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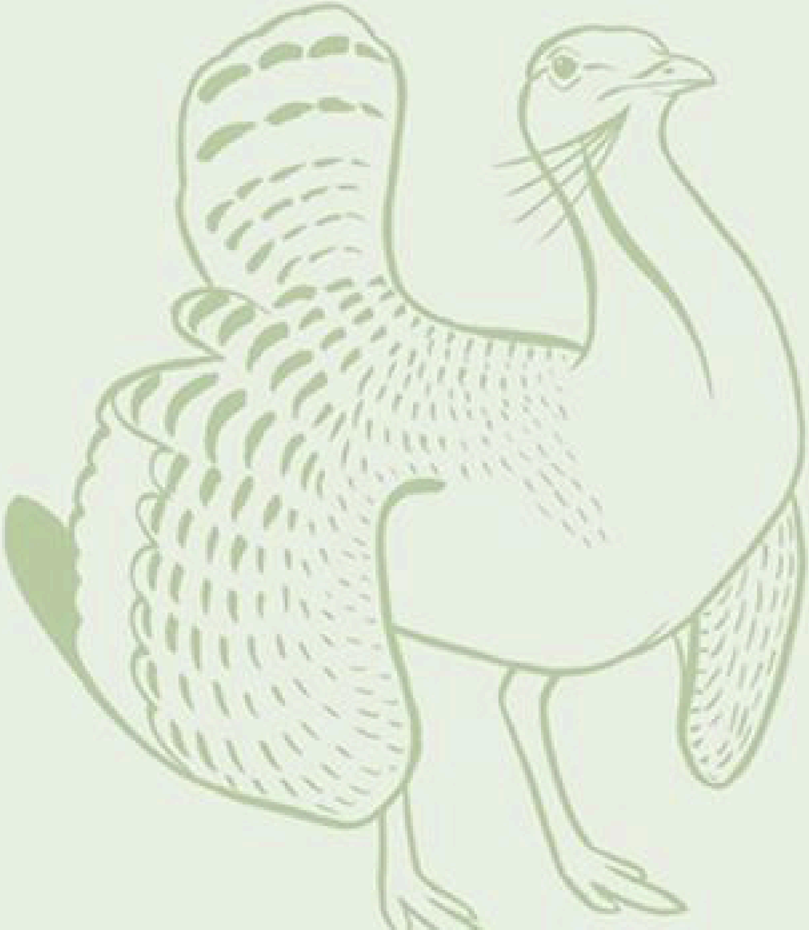

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Wintering waterbird assemblage in an emerging wetland of West Bengal, India: characterization for conservation management

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Abstract Waterbirds constitute a prominent biota and reflect the ecosystem health and functionality of the freshwater wetlands. Documentation of the bird species assemblages of wetlands is therefore carried out as a part of monitoring of wetlands from a sustainability viewpoint. Using the emerging wetland of Purbasthali, West Bengal, India, as a model study area, the diversity of the associated bird species was estimated to supplement necessary information for conservation management of birds and ecosystems. The point count method was applied to count the waterbirds from each sighting location with a 25 m radius covering 360° arc and the counting period lasted 10 min for each site, and counts were made in the winter of 2016/2017. The data on the waterbirds encountered were recorded and subjected to diversity analysis, including the residential status, global population trend and feeding guilds. Apparently, the wetland was considered as suitable habitat for 27 waterbird species, which could be grouped under 24 genera, 10 families and 5 orders. Among these, the family Anatidae with maximum relative density and abundance dominated in the wetland. Out of the 27 recorded species, 5 species were widespread winter visitors, 3 species widespread resident, as well as, widespread winter visitors and 2 species were sparse local winter visitors. A globally near threatened species, the Black-headed Ibis *(Threskiornis melanocephalus)* was very common in the sampling sites. The waterbird assemblage in the wetland was dominated by carnivores followed by omnivores and herbivores. The abundance of the waterbirds with considerable variations in the foraging guild reflects availability and exploitation of multiple resources of the Purbasthali wetlands. Prominence in the differences in relative abundance of the different waterbirds could be linked with the heterogeneity in the habitat quality. The present information on waterbird assemblage calls for appropriate measures for conservation of the species and appropriate management of Purbasthali wetlands.

Keywords: emerging wetland, waterbird, habitat suitability, conservation

Összefoglalás A vízimadarak többnyire feltűnő együtteseket alkotnak, és jól tükrözik az édesvízi élőhelyek ökoszisztémájának állapotát és működését. A vizes élőhelyek madárfaj-együtteseinek dokumentálását ezért ezen élőhelyek fenntarthatósági szempontú monitorozásának részeként végzik. Az indiai Nyugat-Bengáliában található Purbasthali nevű vizes élőhely, mint mintaterület vizsgálata az ott előforduló madárfajok sokféleségére vonatkozó becslések szerint olyan kiegészítő információkat szolgáltat, amelyek szükségesek a madarak és az ökoszisztémák megfelelő természetvédelmi kezeléséhez. A vízimadarak számlálására minden egyes megfigyelési helyen pontszámlálási módszert alkalmaztak egy 25 m sugarú körben, 360°-os ívet lefedve, egyenként 10 perces időtartamban. A vizsgálat 2016/2017 telén zajlott. A megszámlált vízimadarak adatait rögzítették és diverzitás elemzésnek vetették alá, beleértve az élőhelyi státuszt, a globális populációs trendet és a táplálkozási guildeket is. Ez a vizes élőhely 27 vízimadárfaj számára bizonyult megfelelőnek, amelyek 24 nemzetségbe, 10 családba és 5 rendbe sorolhatók. A területen az Anatidae család dominált, maximális relatív denzitással és abundanciával. A 27 megfigyelt faj közül 5 gyakori téli vendég, 3 gyakori állandó faj, valamint gyakori téli vendég, 2 faj pedig ritka helyi téli vendég volt. Egy globális léptékben mérve mérsékelten veszélyeztetett faj, a feketefejű íbisz *(Threskiornis* *melanocephalus)* nagy gyakorisággal fordult elő a mintavételi területeken. A vizes élőhelyen megfigyelt vízimadarak együttesében, sorrendben, a ragadozók, majd a mindenevők és a növényevők domináltak. A vízimadarak gyakorisága és a táplálkozási guildek jelentős eltérései jól mutatják a Purbasthali vizes élőhely rendelkezésre álló erőforrásainak gazdagságát és kiaknázhatóságát. Az egyes vízimadárfajok relatív abundanciájában mutatkozó különbségek összekapcsolhatók az élőhely minőségének heterogenitásával. A vízimadarak együtteseiről jelenleg rendelkezésre álló információk megfelelő intézkedéseket tesznek lehetővé és szükségessé a faj megőrzése és a Purbasthali vizes élőhelyek kezelése érdekében.

Kulcsszavak: megújuló vizes élőhely, vízimadár, élőhelyek alkalmassága, megőrzés

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Introduction

Wetland ecosystems are the most productive and diversified aquatic ecosystems with higher economic, as well as, ecological values representing a balance between the environment and the life in it (Aynalem & Bekele 2008, Khan 2010). They provide an array of precious services for the environment and civilization (Zedler & Kercher 2005, Biggs *et al.* 2017). Occupying about 6% of the Earth's surface, they are able to maintain ecological sustainability and by providing suitable habitat for a large number of species established as assets of biodiversity (Gopal & Sah 1995, Zedler & Kercher 2005). However, huge resource availability and habitat suitability makes the wetland favourable place for many of the species; among them, waterbirds are the most important component of that ecosystem (Collar & Andrew 1988, Adhurya *et al.* 2020). Waterbirds absolutely depend on wetland habitat for their existence. They use certain wetlands as a microhabitat for their reproduction, nesting and feeding activities (Weller 1999, Hazra *et al.* 2012). Many of these waterbirds spend a certain period of time in one wetland and the rest of the time to another showing seasonal migratory behaviour (Gatto *et al.* 2005). Owing to their insightful response to sudden changes in habitat quality, vegetation composition and resource availability of the wetland, the species composition, diversity and abundance in waterbird populations are strongly affected, thus, they are considered to be an excellent bio-indicator in favour of the health of the ecosystem (Gregory *et al.* 2003, Bhat & Hosetti 2009). Due to the lack of proper knowledge on functioning wetlands, numerous threats arise because of anthropogenic activities that could lead to habitat destruction, pollution and overexploitation of the resource in wetlands. According to some estimates over 50% of the wetland habitats of the world are lost in the last century (Fraser & Keddy 2005, Datta 2011, Davidson 2016). Thus, to protect the wetlands from serious threats spreading of awareness, making conservation policies and their proper implementation is necessary (Islam & Rahmani 2008, Céréghino *et al.* 2014). India is blessed with a large number of wetlands varied from larger to smaller in size occupying about 15.26 million ha of the area (Panigrahy *et al.* 2012, Kumar *et al.* 2016). In addition to 37 wetlands with international importance under Ramsar convention, India has more than five hundred thousand other natural or artificial wetlands containing inland deltas, freshwater ponds, permanent or intermittent freshwater or brackish lakes extended in an area of 2.25 ha (Panigrahy *et al.* 2012). All of these wetlands providing a suitable habitat, which ensures the existence of more than 310 bird species, out of them, 107 winter migrants are known to depend completely on wetland habitat (Manakadan & Pittie 2001, Kumar *et al.* 2005). All of these birds are known to gather in wetlands of different parts of India and their diversity become highest during the winter season (Khan *et al.* 2016, Mazumdar 2019). Diversity of waterbirds is one of the most essential features explaining of the status, productivity and the health of wetlands (Muñoz-Pedreros & Merino 2014). That is the way it is more preferable to observe the community structure of waterbirds to get adequate information about the impact of environmental changes and anthropogenic activities on sustainability of wetland ecosystems (Islam & Rahmani 2008, Mukhopadhyay & Mazumdar 2017). Therefore, in the course of the survey of waterbirds, and estimating the species assemblage pattern, a prediction on the functional integrity of the ecosystem, as well as, planning for proper protection of water bodies can be made.

The wetland of Purbasthali, physiographically an oxbow lake of Gangetic Alluvial Plains (Mandal & Siddique 2018), has long been familiar as it provides suitable habitat for a large number of bird species. However, few works have been accomplished (Jha 2013, Debnath *et al.* 2018) on the diversity and distribution of various bird species that reside in this wetland. This is the first time when a survey was focused mainly on diversity of all kinds of waterbird considering their foraging guilds during midwinter, when they are known to show maximum abundance (Khan *et al.* 2016). Thus, the present study aims to represent the species diversity through field observation and count of the waterbird population during winter, to characterize the species assemblage of waterbirds and to identify the waterbirds with global importance. The study explores the primary observations made on the waterbird species (Mandal & Siddique 2018) emphasizing the trophic guilds, relative abundance and diversity indices. The monitoring of the waterbirds is promoted as a basis for conservation management and sustenance of the ecosystem services derived from the freshwater wetlands. The resultant information of the present study will facilitate planning strategies for conservation of the waterbirds, as well as the emergent freshwater lake of Purbasthali, West Bengal, India.

Material and Methods

Study area

The present study was conducted in Purbasthali Oxbow Lake (regionally named as Chupi char), is actually categorized as a wetland of Gangetic Alluvial Plain (Mandal & Siddique 2018). This wetland is formed naturally by the meandering of Bhagirathi River on its right bank. Geographically, it is situated at the boundary of Burdwan and Nadia districts of West Bengal, extending in between the coordinates of 23°25′55″N to 23°27′52″ N and 88°19′45″ E to 88°21′55″ E *(Figure 1)*. The spatial coverage of water in this wetland area was 3.2 km^2 during the study period. The maximum depth and width of wetland range from 2.5–6.0 m and 450–550 m, respectively. The cold season starts in the beginning of November and lasts for four months, to the end of February. The average temperature was 20 °C during the study period. Throughout its entire area, the wetland possesses a large number of macrophytes like common water hyacinth *(Eichhornia crassipes)*, duckweed *(Lemna minor)*, water lettuce (*Pistia* sp.), water nymph (*Najas* spp.), floating heart (*Nymphoides* spp.), ditch grasses (*Ruppia* spp.), pondweed (*Potamogeton* spp.), etc. Several snail species including *Lymnaea acuminata, Indoplanorbis exustus, Gabbia orcula* and *Gyraulus convexiusculus*

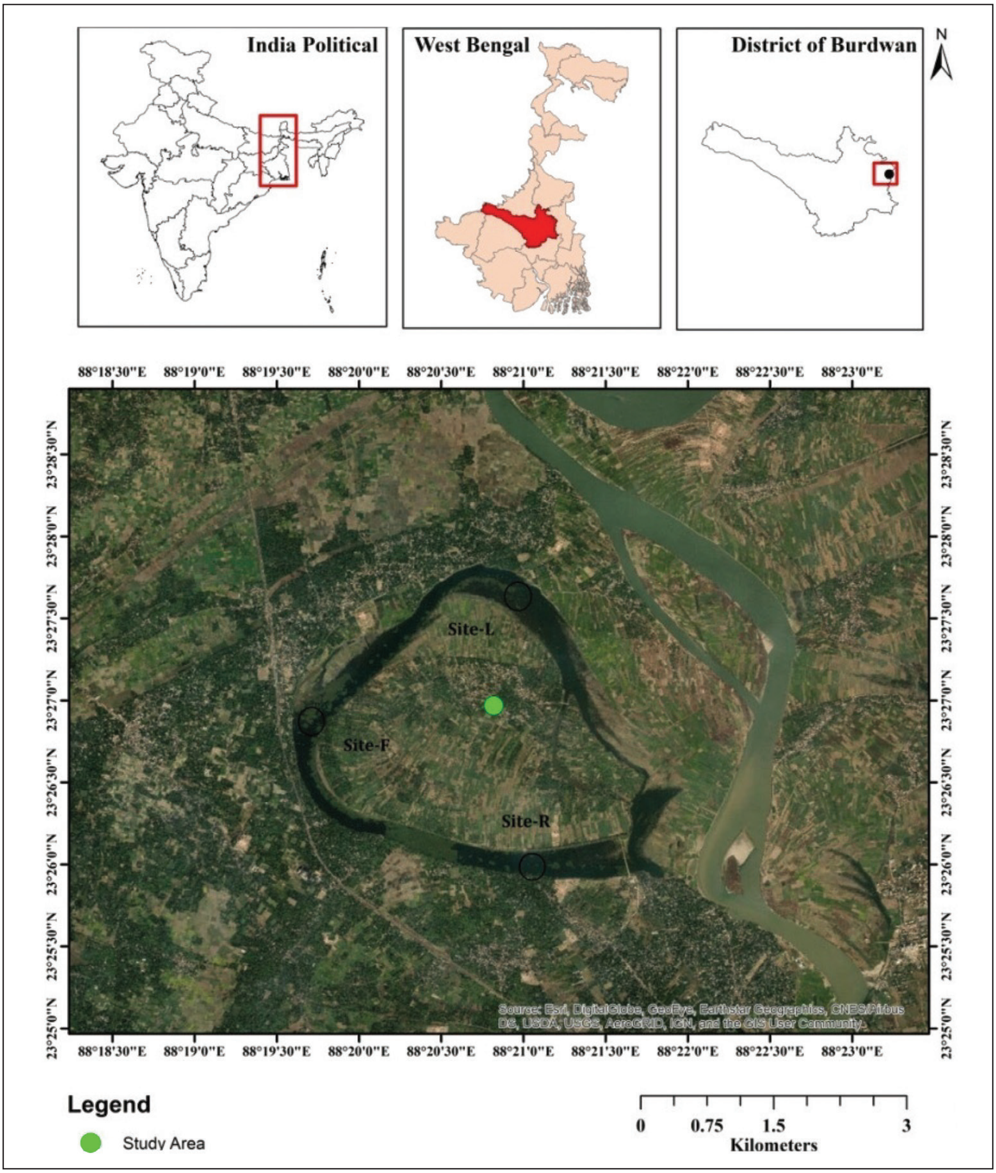

Figure 1. Location of the study area and the sampling sites along the Purbasthali wetland, West Bengal, India

1. ábra A vizsgálati terület és a mintavételi helyek elhelyezkedése a Purbasthali melletti vizes élőhelyen (Nyugat-Bengália, India) were observed attached with the leaves of the macrophytes. Moreover, it also supports a rich diversity of insects, crustaceans and fish. In course of the observations on the wetland waterbirds, selected physicochemical parameters of the wetland water were estimated and the values were (represented as Mean±SE); pH: 7.2±0.27, Total Dissolved Solids: 148±13.8 ppm, Dissolved Oxygen: 7.11±0.19 ppm, NH_4^+-N 0.31±0.04 mg/L, PO_4^{3-}-P: 0.04±0.009 mg/L and NO_3^--N: 0.12±0.02 mg/L.

Census methods

The present study was carried out between November 2016 to February 2017 to have the comprehensive idea about the diversity and abundance of waterbirds at Purbasthali wetland. The waterbird counts were made by employing boat and following the same methods suggested by Wetlands International (2006) and Sinha *et al.* (2011). Each time of the survey, the waterbird counts were started at 8:00 AM and continued until the counts on entire area could be completed, approximately till 6:00 PM in the evening. In this study, the point count method was applied (Bibby *et al.* 1993) to count the waterbirds. In each day, the wetland was entirely surveyed by moving slowly on the boat following the same route and stopping at each preselected vintage point to count the waterbirds. The positions and numbers of vintage points were placed randomly in view of the size of the wetland. Waterbirds counts from all points were repeated at a regular interval of 7days and for each site, counting period lasted for 10 min to minimize the counting errors (Sarkar *et al.* 2014, Muñoz-Pedreros *et al.* 2018, Issa 2019). Birds were counted from each sighting point with a 25 m radius covering 360° arc (Hutto *et al.* 1986, Issa 2019). The intensity of sampling was evaluated through previous censuses following the rarefaction, as well as species accumulation methods (Willson *et al.* 1994). To count the waterbirds, a binocular (Olympus 7×21 PS III) was used and the photographs of waterbirds were taken by Nikon P900 for further identification. The birds were identified observing the photography (Grimmett *et al.* 1998, Kazmierczak & van Perlo 2000, Ali 2002) and recorded for analysis. The data on the relative abundance of each bird species was made with reference to the day surveyed and the data were used for the diversity analysis and estimation of the assemblage characteristics.

Data analysis

The relative diversity (RD_i) of each bird family was estimated following the equation (Torre-Cuadros *et al.* 2007):

$$RD_i = \frac{\text{Number of species in the family}}{\text{Total number of species}} \times 100$$

Relative abundance of each species was measured, from the count of the birds in each day. On this basis, they were categorized into very common (VC) species, where they were found in 75–100% of total visits; common (CO) species observed 50–74% of visits; uncommon (UC) 25–49% of field visits and less common (LC) recorded less than 25% of total visits (Manakadan & Pittie 2001, Tak *et al.* 2010). They were also categorized on the basis of their seasonal dispersal pattern into widespread resident (R), widespread winter visitor (W), widespread resident as well as widespread winter visitors (RW) and sparse local winter visitors (rW) (Kazmierczak 2000). The status of global population trends was collected from the IUCN Red List (del Hoyo *et al.* 1996) and by following IUCN website (https://www.iucnredlist.org/).To obtain the diversity indices of waterbird abundance, the data taken from each study site were analysed separately using Biodiversity Pro software (McAleece *et al.* 1997 Biodiversity Professional; Scottish Association for Marine Science and the Natural History Museum, London, UK). Species richness (S) was calculated by totalling the number of different species present in that area (Mukherjee *et al.* 2015, Issa 2019). Diversity of waterbird species was represented by calculating Shannon diversity index $[H'=-\sum (P_i \ln P_i)]$, Simpson index $[D=1-(\sum n(n-1))/N(N-1)]$ and Shannon H_{max} $[H_{max}=\log_{10}(S)]$. To compare the similarity of population size of each waterbird species the evenness $[J=H'/H_{max}]$ was calculated, where P_i is the proportion of total samples belonging to i^{th}species, n is the total number of waterbirds belongs to a particular species and N includes the total number of waterbirds of all species (Magurran 1988). The relationship among species richness (S), information (H), and evenness (J) in the samples was made by SHE analysis (Buzas & Hayek 1998). Foraging guilds were determined by examining their feeding habitat. In our observation, we found waterbirds species belonging to three feeding guilds, i.e. carnivore (CARV), herbivore (HERV) and omnivore (OMNV) (Ali & Ripley 1980, Hutto 1986). A non-parametric Kruskal-Wallis test followed by multiple pair-wise comparisons (Dunn method with Bonferroni correction) was carried out to analysis the differences between foraging guilds considering their species composition. The statistical analyses were performed following Zar (1999) using the XLSTAT software (Addinsoft 2010).

In order to highlight the indicator value of the waterbird species, the observations were classified into three clusters for application of the IndVal method (Dufrêne & Legendre 1997). The estimation was initiated with the assumption that for each species i, in each cluster j, A_{ij} is the mean abundance of species i in the clusters j, and B_{ij} is considered as the relative frequency of occurrence of species i in the clusters j (Dufrêne & Legendre 1997). The cluster j in the present instance includes discrete observations of certain days representing the term sites in the original definition (Dufrêne & Legendre 1997). The measure A_{ij} represents the specificity that relies on the abundance values while the term B_{ij} represents fidelity, depending on the presence data of the i^{th} species in the clusters. In this estimation, the mean number of individuals in each cluster is used to sum the total individuals in all the observations under a cluster, thereby removing the effect of variations owing to the discrete observation under the various clusters. Similarly the representation of B_{ij} is indicative of the presence of i^{th} species in j clusters among the N number of sites, in N_j number of sites in N_j+ number of sites. Following the calculation of the specificity and fidelity, the indicator value of the species was calculated as the indicator value, IndVal for cluster j, species i=100 x $A_{i,j}$ x $B_{i,j}$; where, $A_{i,j}$ represents specificity and B*i,j* represents fidelity defined in accordance with the IndVal proponents (Dufrêne & Legendre 1997). The IndVal for a species is deduced as: $\text{IndVal}_{speciesi}=\max[\text{IndVal}_{i,j}]$. The significance of the IndVal for a species is judged through a permutation test, carried out in R software ('indicspecies' package) (De Cáceres & Legendre 2009). In order to deduce the indicator value of the waterbirds, the observations were broken into three clusters consisting of 5, 5 and 4 days followed by the application of the data in R software (De Cáceres 2020).

Results

Sampling adequacy and waterbird species records

Sampling efficiency was measured based on the number of waterbird species encountered during the study period (sampling days) which reached in more or less stable form on or after 10th sampling day *(Figure 2)*. During the course of this study, it was recorded that this emerging wetland providing a habitat of 27 waterbird species belongs to 24 genera, 10 families and 5 orders *(Table 1)*. The maximum numbers of waterbird species were recorded under family Anatidae with 7 species (25.93%) followed by Ardeidae with 5 species (18.52%), Rallidae with 4 species (14.81%), Phalacrocoracidae with 3 (11.11%), Jacanidae and Charadriidae each with 2 species (7.41% each), and Podicipedidae, Ciconiidae, Threskiornithidae and Scolopacidae each with 1 species (3.7% each).

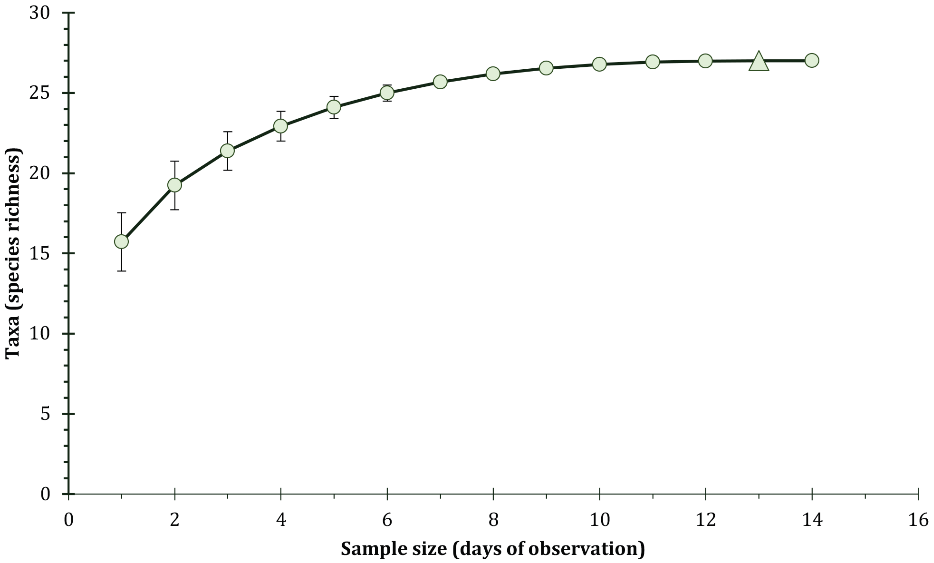

Figure 2. Sample-based rarefaction curve (species accumulation curve) representing the relationship of sampling effort (days) and number of species encountered in the study area. The species saturation (27 species) was observed on the 13th sample (13th day) and is marked with a triangle. The standard error values are provided for each point (sample)

2. ábra Minta-alapú ritkítási görbe (fajtelítődési görbe), amely a mintavételi ráfordítás (napok) és a vizsgálati területen megfigyelt fajok számának összefüggését mutatja. A fajtelítettséget (27 faj) a 13. mintán (13. nap) figyelték meg, ezt háromszög jelöli. Az egyes pontokhoz (mintákhoz) kapcsolódó függőleges vonalak a standard hibaértékeket jelölik

Table 1. List of waterbirds recorded in Purbasthali wetland together with their feeding guild (HERB=herbivore, OMNV=omnivore and CARV=carnivore), residential status (R= widespread resident, W=widespread winter visitor, RW=widespread resident as well as widespread winter visitors and rW=sparse local winter visitor), relative abundance (VC=very common, CO=common, LC=less common, UC=uncommon) andglobal population trend (ST= stable, IN=increasing, DE=decreasing and UN= unknown). *IUCN near threatened species

1. táblázat A Purbasthali vizes élőhelyen megfigyelt vízimadarak táplálkozási guildjeikkel együtt (HERB=növényevő, OMNV=mindenevő és CARV=ragadozó), helyi státuszuk (R=széles körben előforduló állandó faj, W=széles körben előforduló téli vendég, RW=széles körben előforduló állandó, valamint széles körben előforduló téli vendégek és rW=ritka, helyi téli vendég), relatív abundanciájuk (VC=nagyon gyakori, CO=-gyakori, LC=ritkább, UC=nem gyakori) és globális populációs trendjük (ST=stabil, IN=növekvő, DE= csökkenő és UN=ismeretlen). * IUCN mérsékelten veszélyeztetett fajok

Order	**Family**	**Common Name**	**Scientific Name**	**Acronym used**	**Feeding guild**	**Residential status**	**Relative abundance**
Anseriformes	Anatidae	Cotton Pygmy Goose	*Nettapus coromandelianus* (Gmelin, 1789)	NCO	HERB	R	VC
		Gadwall	*Mareca strepera* (Linnaeus, 1758)	MST	HERB	W	CO
		Lesser Whistling-duck	*Dendrocygna javanica* (Horsfield, 1821)	DJA	OMNV	R	VC
		Red Crested Pochard	*Rhodonessa rufina* (Pallas, 1773)	RRU	HERB	W	CO
		Ruddy Shelduck	*Tadorna ferruginea* (Pallas, 1764)	TFE	OMNV	rW	LC
		Ferruginous Pochard	*Aythya nyroca* (Güldenstädt, 1770)	ANY	OMNV	rW	LC
		Northern Pintail	*Anas acuta* (Linnaeus, 1758)	AAC	OMNV	W	LC
Charadriiformes	Jacanidae	Bronze-winged Jacana	*Metopidius indicus* (Latham, 1790)	MIN	OMNV	R	VC
		Pheasant-tailed Jacana	*Hydrophasianus chirurgus* (Scopoli, 1786)	HCH	OMNV	R	LC
	Charadriidae	Grey-headed Lapwing	*Vanellus cinereus* (Blyth, 1842)	VCI	CARV	W	CO
		Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	VIN	CARV	R	UC
	Scolopacidae	Wood Sandpiper	*Tringa glareola* (Linnaeus, 1758)	TGL	CARV	W	CO
Gruiformes	Rallidae	Common Coot	*Fulica atra* (Linnaeus, 1758)	FAT	OMNV	RW	VC

Order	Family	Common Name	Scientific Name	Acronym used	Feeding guild	Residential status	Relative abundance
		Purple Swamphen	*Porphyrio porphyrio* (Linnaeus, 1758)	PPO	OMNV	R	LC
		Common Moorhen	*Gallinula chloropus* (Linnaeus, 1758)	GCH	OMNV	R	LC
		White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	APH	OMNV	R	LC
Pelecaniformes	Ciconiidae	Asian Openbill	*Anastomus oscitans* (Boddaert, 1783)	AOS	CARV	R	VC
	Threskiornithidae	*Black-headed Ibis	*Threskiornis melanocephalus* (Latham, 1790)	TME	CARV	R	VC
Pelecaniformes	Ardeidae	Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	BIB	CARV	R	VC
		Intermediate Egret	*Ardea intermedia* (Wagler, 1829)	AIN	CARV	R	LC
		Indian Pond-Heron	*Ardeola grayii* (Sykes, 1832)	AGR	CARV	R	VC
		Little Egret	*Egretta garzetta* (Linnaeus, 1766)	EGA	CARV	R	VC
		Purple Heron	*Ardea purpurea* (Linnaeus, 1766)	APU	CARV	RW	LC
	Phalacrocoracidae	Indian Cormorant	*Phalacrocorax fuscicollis* (Stephens, 1826)	PFU	CARV	R	LC
		Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	MNI	CARV	R	LC
		Great Cormorant	*Phalacrocorax carbo* (Linnaeus, 1758)	PCA	CARV	RW	LC
Podicipediformes	Podicipedidae	Little Grebe	*Tachybaptus ruficollis*(Pallas, 1764)	TRU	CARV	R	VC

Residential status, global population trends and relative abundance of recorded species

Out of 27 recorded waterbird species, 17 species (62.96%) were widespread residents (R), 5 species (18.52%) widespread winter visitors (W), 3 species (11.1%) widespread resident as well as widespread winter visitors (RW) and 2 species (7.41%) were sparse local winter visitors (rW) (Kazmierczak 2000). Among all reported waterbirds varieties, only one species, the Black-headed Ibis, was near threatened according to the IUCN, very common to the studied area and rest are the least concerned species. Considering the global population trend, it was noticed that the surveyed area holds 3 waterbird species known to follow the stable population trend (ST), 5 increasing (IN), 10 with unknown (UN) and noticeably,9 species known to follow the decreasing (DE) population trend. We observed that among these nine species three were very common (VC), one species was common (CO) and five species were less common (LC) to the area *(Figure 3)*. Three species (Lesser Whistling Duck, Black-headed Ibis and Little Grebe) following globally declining population (DE) trend were found very common (VC) to the studied area while one species (Grey Headed Lapwing) of the global DE category was common (CO) and the other five species (Ferruginous Pochard, Northern Pintail, Pheasant Tailed Jacana, Intermediate Egret and Purple Heron) of the same category were less common to the area. Mean±SE of the total number of species of Lesser Whistling Duck and Little Grebe were 34.14±5.95 and

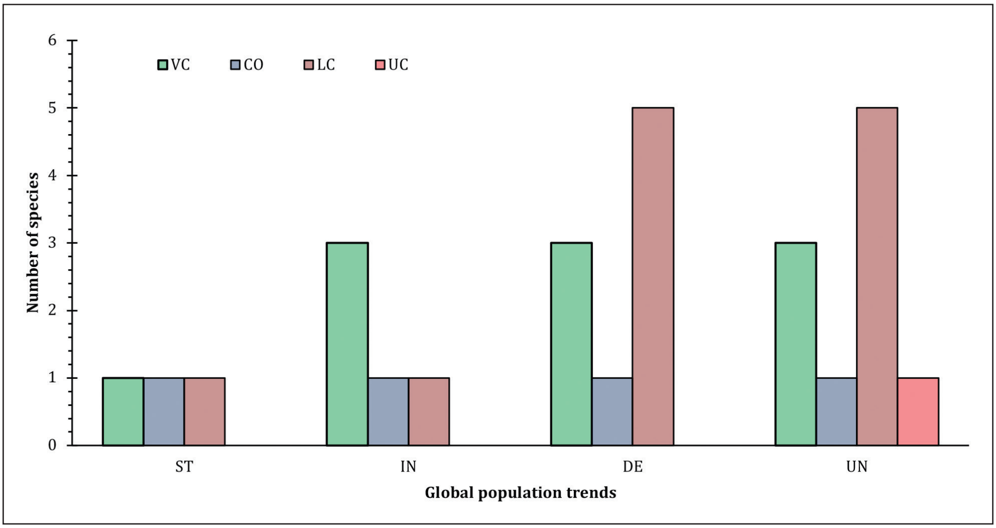

Figure 3. Comparison of relative abundance (VC, CO, LC and UC) and global population trend (ST, IN, DE and UN) of bird species observed from Purbasthali, West Bengal, India (VC=very common, CO=common, LC=less common, UC=uncommon, ST=stable, IN=increasing, DE=decreasing and UN=unknown)

3. ábra Az indiai Purbasthaliban (Nyugat-Bengália) megfigyelt madárfajok relatív abundanciájának (VC, CO, LC és UC) és globális populációs trendjének (ST, IN, DE és ENSZ) összehasonlítása (VC=nagyon gyakori, CO=gyakori, LC=kevésbé gyakori, UC=ritka, ST=stabil, IN=növekszik, DE=csökken és UN=ismeretlen)

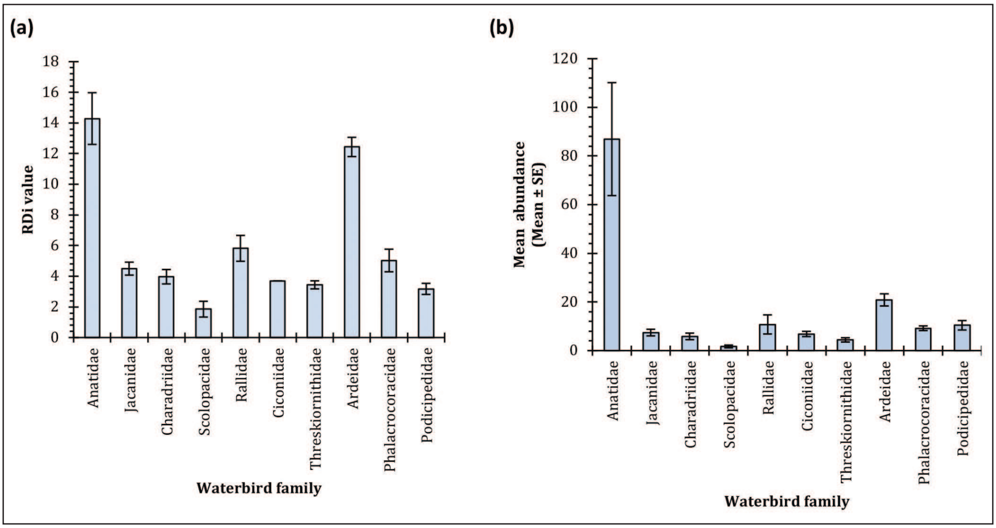

Figure 4. a – Relative diversity (RD_i) and b – mean abundance of various waterbird families recorded from Purbasthali wetland, West Bengal, India

4. ábra a – Relatív diverzitás (RDi) és b – átlagos abundancia az indiai nyugat-bengáli Purbasthali vizes élőhelyről feljegyzett vízimadár családok esetén

10.42±1.94, respectively. Observing the relative abundance of all waterbird species, it was reported that ten species (37.04%) were very common (VC), four species were common (14.81%), while another twelve species (44.4%) were less common (LC) and the remaining one species were uncommon (CO). The relative abundance was the highest for Red Crested Pochard (38.57±22.38) and the lowest for Purple Heron and Little Cormorant (0.21±0.11 for each). Throughout the sampling period, a total of 540 Red-crested Pochard was counted, which was the maximum in number compared to the other species.

Relative diversity (RD_i) and mean abundance of various waterbird families

Comparing the relative diversity (RD_i), as well as mean abundance values among the recorded avian families *(Figure 4a, b)* revealed that Anatidae having maximum relative diversity (7 species, RD_i=14.29±1.69) and mean abundance value, followed by Ardeidae (5 species, RD_i=12.43±0.62) represented dominant group, while Scolopacidae with a single species (RD_i=1.85±0.51) poorly represented in the study area.

Analysis of diversity indices

Along the wetland habitat, the values of diversity indices were recorded for waterbirds as species richness (S=15.71±0.94), Shannon-Weiner diversity index (H'=2.24±0.08), Simpson's Diversity (D=0.84±0.02), Shannon evenness (J=0.82±0.03) and maximum diversity value (H_{max}=2.73±0.05).As revealed through the output of SHE analysis *(Figure 5)*, the association among S (species richness), H (information), and E (evenness) in the

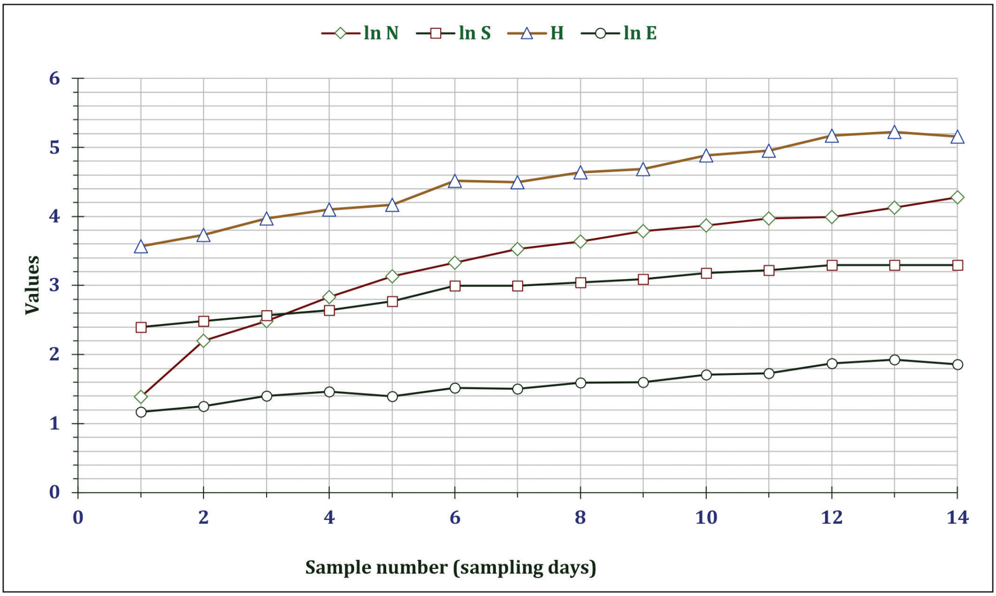

Figure 5. Plot of SHE analysis calculated on four months data of relative abundance of 27 waterbird species reported in Purbasthali wetland, West Bengal, India. Each point in x-axis represents a sampling day consisting of multiple observations

5. ábra Az SHE-analízis görbéje 27 vízimadárfaj relatív abundanciájának négy hónapos adatai alapján számolva, amelyeket a Purbasthali vizes élőhelyen figyeltek meg Nyugat-Bengáliában (India). Az x tengely minden pontja egy mintavételi napot jelent, amely több megfigyelésből áll

samples can be interpreted properly. For this multispecies community as the number of individuals (N) accumulated with each sampling effort, the species richness (S) usually increases. In the meantime, it was very prominent in the studied community that H increases as InS increases and InE decreases with the accumulation, while the ratio InE/lnS remain constant. Kind of departures from the linear trends specified a diversified community.

Feeding guilds of waterbirds

The recorded waterbird species were divided into three feeding guilds observing their habitat use and foraging behaviour during the survey. The results revealed that the waterbird species in that habitat were dominated by carnivore group (51.85%) followed by omnivore (37.04%) and herbivore (11.11%) *(Figure 6)*. Comparing the relative abundance of the species among the foraging guilds it was observed that they varied significantly (Kruskal-Wallis test: K=35.03, df=2, P<0.05). For a more specific comparison of single variable between feeding guilds a pair wise post-hoc comparisons using Dunn's test with the Bonferroni correction was carried out (between carnivore and herbivore: 27.179, P<0.0001; between carnivore and omnivore: 13.321; P<0.0037, and between herbivore and omnivore: 13.857, P<0.0025; with the critical value for two tailed Dunn's comparison being 10.994; Bonferroni corrected significance level: 0.0167). Thus the significant differences between

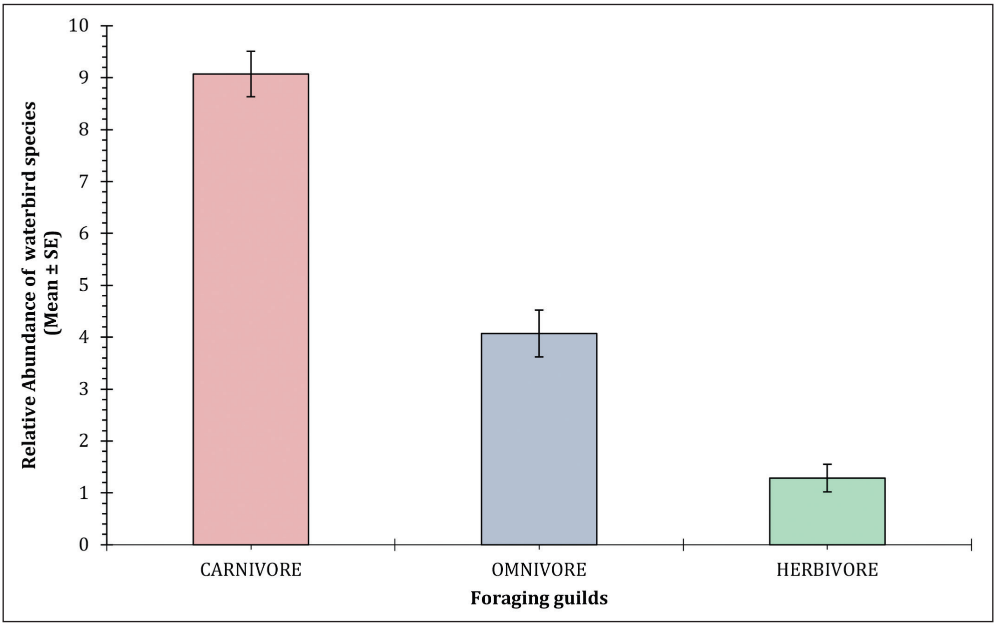

Figure 6. Relative abundance of waterbird species belonging to three foraging guilds recorded in the study area

6. ábra A vizsgálati területen megfigyelt vízimadárfajok relatív abundanciája három különböző táplálkozási guild szerinti megoszlásban (carnivore – ragadozó, omnivore – mindenevő, herbivore – növényevő)

each pair of foraging guilds in the study area (Bonferroni Dunn; P<0.05) are indicative of diverse species assemblages of waterbirds in the Purbasthali wetlands.

Indicator value for waterbird species

The indicator values of waterbird species observed in the samples are shown in *Table 2* along with the relative abundance in the samples. Following preliminary assessment the IndVal differed for the species and between the clustered samples. However, on the basis of the results of the permutation tests, the IndVal values of the four bird species, RRU, PPO, APU, and MST bear significance at P<0.001 level as shown in *Table 2*. In addition, the IndVal of TRU was also significant when values from two groups (clusters) were taken together. Thus, out of 27 species recorded, five species remained significant in terms of their IndVal score based on the relative abundance in the samples.

Discussion

The study site Purbasthali oxbow lake, situated in Burdwan, India is a natural emerging wetland, which features a range of waterbird species during the winter season (November

Table 2. The relative abundance of the representative waterbirds and the contribution to the IndVal in the three clusters deduced from the samples. A randomization test (multilevel pattern analysis, indicspecies package of R) for the IndVal was carried out to conclude about the significant values of the respective species. A and B corresponds to the specificity and fidelity respectively as described in the IndVal equation

2. táblázat A vízimadarak relatív abundaciája és IndVal értékei. A randomizációs teszt (többszintes mintázat elemzés az indicspecies R csomagban) megadja a fajok IndVal értékeihez tartozó szignifikancia értékeit. A és B az IndVal egyenlet megfelelő paramétereit mutatja

Acronym	**Range, Mean±SE**	**IndVal,**	**Acronym**	**Range, Mean±SE**	**IndVal,**
NCO	2–16 7.21±1.02	**8.1188**	GCH	0–3 0.43±0.25	6.67
MST	0–25 6.07±1.95	17.941	APH	0–2 0.29±0.16	9.38
DJA	12–80 34.14±5.95	**8.9958**	AOS	4–18 6.86±1.07	10.42
RRU	0–300 38.57±22.37	**21.481**	TME	0–11 4.43±0.88	**11.935**
TFE	0–2 0.36±0.2	**7.5**	BIB	3–14 6.14±0.84	**8.8372**
ANY	0–2 0.29±0.19	**12.5**	AIN	0–2 0.29±0.16	3.125
AAC	0–2 0.29±0.16	**6.25**	AGR	5–25 11.07±1.47	**9.9355**
MIN	2–21 7.07±1.32	**9.3434**	EGA	0–7 3.14±0.53	10
HCH	0–2 0.38±0.2	2.5	APU	0–1 0.21±0.11	18.75
VCI	0–17 4.29±1.42	8.8	PFU	3–15 8.57 ± 0.96	**8.3333**
VIN	0–8 1.57±0.66	6.82	MNI	0–2 0.21±0.15	8
TGL	0–6 1.71±0.57	**3.67**	PCA	0–3 0.43±0.25	6.67
FAT	0–44 8.43±3.03	15.89	TRU	0–24 10.43±1.94	11.47
PPO	0–12 1.64±0.97	**18.75**			

Multilevel pattern analysis; Total number of species: 27; Selected number of species: 5; Number of species associated to 1 group: 4; Number of species associated to 2 groups: 1 Group 2, species 4, Group 2+3=1 species (STAT–represents the values obtained through random permutation in R)

Group 2 only	A	B	STAT	P value
RRU	0.9297	1	**0.964**	0.024
PPO	0.9014	1	**0.949**	0.021
APU	0.8889	1	**0.943**	0.026
MST	0.7593	1	**0.871**	0.050
Group 2+3				
TRU	0.8887	1	**0.942**	0.016

to February). Information on the characteristic species assemblage of waterbirds can be deduced through the present check list. A total of 27 waterbird species were recorded during the survey period from November 2016 to February 2017. Among the waterbird species, 17 were residents, 5 species were widespread winter visitors, 3 species were widespread resident as well as widespread winter visitors and 2 species were sparse winter visitors, which were prominent in the census within this microgeographic habitat. The bird species assemblages in a similar wetland bearing significance for the migratory birds, the Santragachi *jheel*, Howrah, West Bengal, India, 22 bird species were observed (Singha Roy *et al.* 2011). In the Santragachi *jheel*, the water quality parameter and the growth of the weeds were directly influenced by the abundance of the birds, which provides a reflection of the multifunctional role of the birds in sustaining the wetland ecosystems (Singha Roy *et al.* 2011, Adhurya *et al.* 2020). Among the 22 species, 15 species of birds were migratory (Khan 2010) and were observed through continuous monitoring over several years. Similarly, in the wetlands of Alipurduar and Coochbehar, West Bengal, 27 water bird species were recorded with 13 being migratory (Chatterjee *et al.* 2020), with various feeding techniques and foraging habitats. Coexistence of the birds in these wetlands can possibly be a reflection of the habitat and niche segregation (Chatterjee *et al.* 2020), as well as temporary exploitation of the habitat, particularly during the winter season, by the winter visitors (Khan 2010, Singha Roy *et al.* 2011). Similar observations are also available for three different wetlands spread across West Bengal, where consistent presence of 19 species and additional 5species as vagrants were observed over a long period (Khan *et al.* 2016). While our observations on the number of the bird species remain comparable to the Santragachi *jheel*, and other regions of West Bengal, the earlier observations from Purbasthali appear to be considerably higher (74 species reported by Mandal & Siddique 2018, 86 species reported by Debnath *et al.* 2018), particularly because of the inclusion of several nonaquatic bird species. Similarly, in two other wetlands in Jalpaiguri, West Bengal, 42 and 80 species of birds were observed (Datta 2011), of which 63 were waterbirds, mostly migratory. On a comparative scale, the species composition observed in the present instance, the variations appear to be similar to those observed in the wetlands in similar geographical conditions (Khan 2010, Hazra *et al.* 2012, Khan *et al.* 2016, Mukhopadhyay & Mazumdar 2017, Mazumdar 2019, Chatterjee *et al.* 2020). The incidence of winter migratory waterbirds in the area indicates that the wetland provides suitable habitat not only for resident species but also for migratory birds (Hazra *et al.* 2012, Menon *et al.* 2015, Mazumdar 2019). A globally near threatened species, the Black-headed Ibis, was very common in the wetland of Purbasthali. During the survey, nine waterbird species were encountered with globally declining population trend. Among them, three were very common, one species was common and five species were less common in the habitat. Higher values of diversity indices revealed significant species richness comparing to the size of the wetland. It may be due to the availability as well as the variety of alternative food resources for birds over the favourable habitat for nesting and breeding (Hossain & Aditya 2016). Considering the vegetation of the studied wetland, it was noticed that various macrophytes like *Eichhornia*, *Lemna*, *Nymphoides*, *Najas*, *Typha*, *Phragmites* distributed the entire area. Though high vegetation in a wetland may negatively influence the waterbird community, but for some other number of birds like Common Moorhen, White-breasted Waterhen and Purple Swamphen, it could provide a perfect breeding ground (Kosiński 1999, Khan *et al.* 2016). In addition to that, due to the close association of various macroinvertebrates and fishes with hydrophytes, it could favour the diving waterbirds unlike the dabblers as the closed water surface reduced their feeding area (Khan 2010). However, in this study, we found relatively higher abundance of carnivores than omnivores followed by herbivores. Migratory waterbirds being an opportunist and having higher adaptability during winter season to the wetland when reducing water level exposed some new emergent areas, which provided appropriate feeding habitat for all waterbirds belonging from every feeding guild. For this unmanaged wetland, the similarities in habitat quality are supposed to sustain greater diversity (Kaminski *et al.* 2006). Starting from November, the species richness began to rise in this wetland and continued to increase up to the February. Continuous increase in migratory waterbirds during winter in this site may be due to its favourable climatic condition as well as availability of resource and habitat. An association of hydrophytes with perennial wetlands acting as a microhabitat for macroinvertebrates and fish assemblages, which serve as a feeding ground for many waterbirds as well as supporting various breeding population to that area. During the study, the estimation and monitoring of different physicochemical characteristics of wetland like quality and depth of water, size of the wetland, abundance of food resource (molluscs and fishes), suitability of roosting sites and observing higher species diversity with the available existence of some species whose population are now declining globally, suggest that the wetland of Purbasthali is now qualified as a perfect habitat for waterbirds, therefore, the effective management is required. From sustained monitoring (Panigrahy *et al.* 2012) of the bird assemblages from protected waterbodies like Santragachi, West Bengal (Khan 2010, Singha Roy *et al.* 2011), and other wetlands in West Bengal (Hazra *et al.* 2012, Khan *et al.* 2016) Okhla, India (Mazumdar 2019) and the present study, it can be revealed that this wetland provides an essential wintering habitat for varieties of waterbird species. However, further observations to that place are also required during other seasons and over the year to figure out the values of the wetland ecosystem for waterbird sustainability.

In the emerging wetland Purbasthali, 27 waterbird species, categorized under 24 genera, 10 families and 5 orders were observed with varying relative density. Among all, the three types of foraging guilds (herbivore, carnivore and omnivore) were recorded, the representations were the highest for the carnivores, probably due to the adequacy of macroinvertebrates and fishes as food sources. Earlier observations (Mukherjee *et al.* 2002, Hossain & Aditya 2016) indicated that waterbirds frequently forage outside wetland to the adjacent agricultural lands and sometime a few of them were known to inhabit in artificial lands like adjoining paddy fields or another crop fields, which usually provide an alternative habitat for them in degraded landscape. Increasing agricultural practices with the indiscriminate use of chemical pesticides can cause a severe impact on the waterbird population of the Purbasthali wetland. Pollution of water by anthropogenic activities, uncontrolled fishing habits and most recently sprouting of a number of brick kilns at the edge of wetland area were spotted as significant threats of the wetland. Instead of the existence of threats, interference of proper management like environment friendly agricultural practices, controlling fishing activities, restraining constructions adjacent to the wetland area may help to conserve waterbird species in several ways (Rahmani *et al.* 2016). However, the studied wetland of Pubasthali has already exposed its potentiality as a suitable habitat for both resident and migratory waterbirds, now it is our turn to protect its habitat by leaving it undisturbed and allow it to stay with its own identity by implementing an enduring conservation programme.

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Influence of habitat features of urban streetscapes on richness and abundance of avian species

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Abstract In human-dominated landscapes, roads are known to negatively influence birds causing decline in species richness, as well as reduction in the number of avian species. However, linear stretches of green spaces formed by roadside plantations in urban streetscapes can support diverse avian communities. In spite of being an integral habitat feature of urban areas, there is a clear paucity of studies on avian diversity in urban streetscapes. The present study was carried out in Kolkata, where data on avian species richness and abundance was collected from 16 randomly placed belt transects (replicates), each of 500 m length and 20 m width, on different major roads throughout the study area keeping a minimum gap of 200 m between adjacent transects to avoid data overlapping. Each of these transects were traversed on foot twice in a month from January to March 2017 during days with calm weather conditions. We recorded 31 species of birds belonging to 8 orders and 19 families, of which maximum species belonged to the order Passeriformes (13 species). We found that both abundance and species richness of birds in transects with higher number of trees (78±4.1 individuals and 19.55±1.703 species of birds) were significantly higher than transects with fewer trees (53.74±2.5 individuals and 9.5±0.789 species of birds). Amongst various habitat features along these streetscapes, the total number of trees positively influenced both species richness (GLMM: $F_{1, 90}$=14.485, P<0.05) and abundance of birds (GLMM: $F_{1, 90}$=8.081, P<0.05). However, the other land use variables (i.e. number of bushes, waterbodies, markets and buildings) neither influenced the abundance of birds nor the species richness. Our findings can be useful for urban development to perceive the importance of various habitat features in urban streetscapes in sustaining avian diversity.

Keywords: avifauna, species richness, streetscape, roadside vegetation, habitat, urbanization

Összefoglalás Az emberi tevékenység révén átalakított környezetben az utak negatív hatással vannak a madarakra, csökkentik a fajok számát és a populációk egyedszámát. Ezzel együtt az utak mentén kialakított zöld növényzeti sávok diverz madárközösségnek adhatnak otthont. Habár az útmenti növényzet a városi élőhely integráns része, ritkán vizsgálják az itt előforduló madarakat. E vizsgálatban Kalkutta főútjai mentén 16, egyenként 500 m hosszú és 20 m széles transzektben vizsgáltuk az előforduló madárfajok számát és denzitását. A madárszámolásokat gyalog végeztük 2017. január és március között, transzektenként 6 alkalommal. Összesen 31 fajt (8 rendből, 19 családból) figyeltünk meg, melyek nagy része énekesmadár volt (Passeriformes). Azokban a transzektekben, amik mentén sok fa található, a madarak denzitása és fajszáma is nagyobb volt (78±4,1 egyed 19,55±1,703 faj), mint azokban a transzektekben, amelyek mentén kevés fa volt (53,74±2,5 egyed és 9,5±0,789 faj). A vizsgált élőhelyi tulajdonságok közül kizárólag a fák száma volt hatással a madarak denzitására (GLMM: $F_{1, 90}$=8,081, P<0,05) és a fajszámra (GLMM: $F_{1, 90}$=14,485, P<0,05). A többi változó, mint a bokrok száma, víztestek, piacok és épületek száma sem a fajszámra, sem a madarak denzitására nem volt hatással. Eredményeink hasznosak lehetnek a városfejlesztési tervek kidolgozásában, a városi élőhelyek kialakításában és így a madarak diverzitásának megőrzésében.

Kulcsszavak: madárfauna, fajgazdagság, utcakép, útmenti növényzet, élőhely, urbanizáció

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Introduction

Cities and towns across the globe are ever-expanding with explosion in human population (Fuller *et al.* 2009). As compared to the year 2000, a three-fold increase in urban areas have been predicted by 2030 (Seto *et al*. 2012) leading to large scale loss, degradation and fragmentation of habitats coupled with environmental changes (McKinney 2006, Bar-Massada *et al.* 2014), destruction of forests (Fischer *et al.* 2007), reduction of wilderness areas (Olagunju 2015) and increase in impervious surfaces (Barnes *et al*. 2001), which often threatens the survival of many species worldwide in these areas (Marzluff *et al*. 2001, Sol *et al.* 2017). Animals in urban areas also face greater amount of anthropogenic pressures (such as increased vehicular traffic, air, noise and light pollution, loss of vegetation cover and increased impervious surfaces). In such scenario, various native greenspaces serve as important and remnant patches of habitats for wildlife thriving in human-dominated landscapes (Miller 1997, Milton 2002). Green spaces in urban areas are often rich in biodiversity (Shwartz *et al.* 2014a, 2014b) and have long been identified to increase the functional connectivity for the local fauna (Ikin *et al.* 2015). Studies on the richness and diversity of birds have been carried out in urban greenspaces, like parks, forest remnants, cemeteries (Lussenhop 1977, Kocian *et al.* 2003, Croci *et al.* 2008, Nielsen *et al.* 2014).

Roads are often known to negatively influence birds by increasing impervious surfaces, leading to fragmentation and destruction of habitats; as well as increase traffic and consequent mortality being hit by speeding vehicles; elevated levels of air, noise and light pollutions etc., which often decline the abundance of various avian species (Lim & Sodhi 2004, Cooke *et al.* 2020). Increasing area of roads have been reported to lead to a decline in species richness (Villasenor *et al.* 2017). Nevertheless, the linear stretches of green spaces formed by roadside plantations are an integral habitat feature of urban areas (Gonzalez Sosa *et al.* 2017), which increase the functional connectivity to the local fauna (Ikin *et al.* 2015). Urban streetscapes are also known to support diverse avian communities (White *et al.* 2005). However, there is a clear paucity of studies on avian diversity in urban streetscapes from highly populated countries with intense population explosion and rapid urbanization, like India. Therefore, we carried out this study in an urban area to (i) make an assessment of the community composition, species richness and abundance of avifauna in different streetscapes and (ii) to assess which habitat features influenced the abundance and species richness of birds. Our findings can be useful in the management of urban streetscapes sustaining the avian diversity thriving there.

Methods

Study design

We carried out this study in Kolkata (22.330°N, 88.300°E; 6.4 m a.s.l.) *(Figure 1)*, which spreads linearly along the banks of the Hooghly River and inhabited by around 4.5 million residents. This study area is located in the lower Ganges basin and one of the largest urban agglomeration in India and also of the world. Data on avian species richness and abundance was collected following the belt-transect method (Bibby *et al.* 2000, Sutherland 2006). 16 belt transects (replicates), each of 500 m length and 20 m width were randomly placed on different major roads throughout the study area keeping a minimum gap of 200 m between adjacent transects to avoid data overlapping. All transects were well dispersed from each other (Hurlbert 1984) and representative of the entire study area *(Figure 1)*. Each of these transect was traversed on foot twice in a month from January to March 2017, which resulted in a total of six surveys per transect. Surveys were carried out during days with calm weather

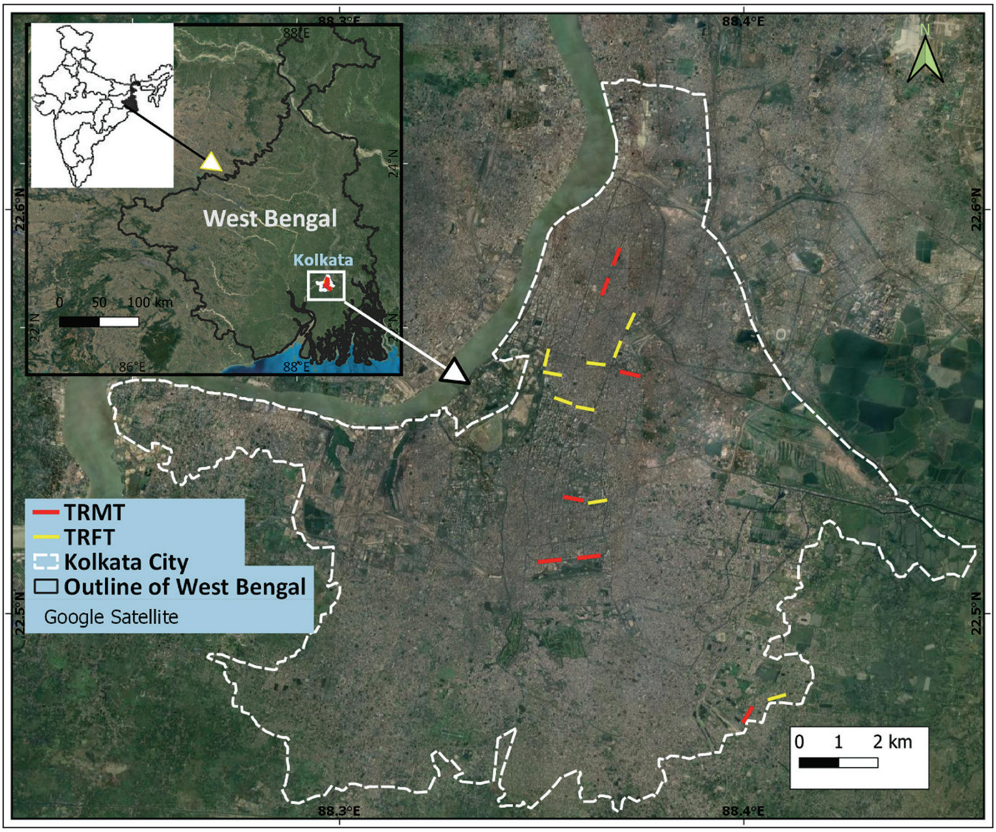

Figure 1. Map of study area in West Bengal, India showing the locations of transects with many trees (TRMT) and with few trees (TRFT)

1. ábra A vizsgálati terület térképe (Kalkutta, Nyugat-Bengál, India). A transzektek helyét piros (transzekt sok fával) és sárga (transzekt kevés fával) vonalak jelölik conditions (without rain and strong wind) and during morning hours (between 06:00 and 09:30), when birds are usually most active. While traversing the transect, we collected data on the abundance and species richness of the avifauna. Any bird noticed horizontally 10 m on either side of transects were recorded, as well as, the individuals within 10 m height were recorded. Flying birds were recorded only to get a 'snap-shot' of all the birds recordable from the transect (Bibby *et al.* 2000). However, the 'fly through' and 'fly over' individuals were excluded from subsequent analyses as they would produce overestimates (Bibby *et al.* 2000). Birds were observed either with unaided eyes or with the help of a pair of binoculars (Nikon 8 × 40) and photographs were taken with a digital camera (Nikon D500 Digital SLR Camera) for documentation. Birds were identified and their migratory status (resident/migratory) were determined using field guides (Grimmett *et al.* 2016). We also calculated the percentage occurrence score of each species to assess their local abundance, where very common (Vc) bird species were recorded on 80–100% of field visits, common (Co) species on 50–79% of field visits, fairly common (Fc) on 20–49% of field visits and rare (Ra) on less than 20% of the field visits (Khan & Naher 2009). The conservation status of birds and their global population trend were taken from the IUCN Red List (del Hoyo *et al.* 2014). Feeding guild is defined as a group of species with similar foraging habits (Hutto 1985). Our observed avian species were divided into seven guilds, i.e. carnivore (Car), omnivore (Omn), frugivore (Frug), herbivore (Herb), nectarivore (Nect), granivore (Gran) and insectivore (Ins), following Ali and Ripley (1987).

In urban areas, trees (White *et al.* 2005), canopy cover (Alberti & Marzluff 2004, MacGregor-Fors & Schondube 2011), bushes/greenspaces (Ortega-Álvarez & MacGregor-Fors 2009), presence of waterbodies (Johnson *et al.* 2012) and building density (Germaine *et al.* 1998) and other urban structures (Ortega-Álvarez & MacGregor-Fors 2009) are known to potentially influence the diversity and abundance of avian communities present there. Hence, the habitat features like numbers of trees, bushes, waterbodies (any permanent water sources like inland waterbodies, pond, artificial, natural lake, canal which potentially influence bird abundance), buildings and markets (permanent commercial places demarcated by municipal corporation) present within each of the belt transects were assessed from the cloud free high-resolution satellite image of Kolkata (Image acquisition: 24.11.16) obtained from Google Earth Pro software (ver. 7.3.3.7699), which was confirmed through rigorous ground-truthing on field. These were used as habitat features of each transect.

Data analysis

Non-parametric tests were performed for data analysis as Shapiro-Wilk's tests revealed that the abundance ($W=0.972$, $df=96$, $P=0.036$) and species richness ($W=0.782$, $df=96$, $P<0.05$) were non-normally distributed. The mean value of trees in all 16 transects were 9.69±1.34. Therefore, we used presence of 10 trees per 500 m as threshold for classifying the transects into two broad categories like (i) *transects with few trees* (i.e.<10 trees/500 m; henceforth TRFT) and (ii) *transects with many trees* (i.e.>10 trees/500 m; henceforth TRMT). Then Mann-Whitney U test was applied to find out if the species richness and abundance of birds showed any significant variation between TRFT and TRMT.

Table 1. The bird species observed in the streetscapes of Kolkata, West Bengal, India together with their respective taxonomic positions (order, family), feeding guild (Car – carnivore, Omn – omnivore, Herb – herbivore, Nect – nectarivore, Gran – granivore, Ins – insectivore, Frug – frugivore), migratory status (R – resident, M – Migratory), local status (Vc – very common, Co – common, Fc – fairly common, Ra – rare), IUCN status (LC – Least Concern, NT – Near-Threatened), global population trend (Dec. – declining, Inc. – increasing. Stable – stable, and Unknown)

1. táblázat A vizsgálatban megfigyelt madárfajok neve, a faj taxonómiai besorolása (család és rend), táplálkozási típusa (Car: ragadozó, Omn: mindenevő, Herb: növényevő, Nect: nektárfogyasztó, Gran: magevő, Ins: rovarevő, Frug: gyümölcsevő), vonulási kategóriája (R: állandó, M: vonuló), lokális gyakorisági kategóriája (Vc: nagyon gyakori, Co: gyakori, Fc: viszonylag gyakori, Ra: ritka), IUCN státusza, valamint globális populáció trendje (Dec: csökken, Inc: növekszik, Satble: stabil, Unknown: nem ismert)

Common Name	**Scientific name**	**Family**	**Order**	**Feeding guild**	**Local Status**	**IUCN Status**	**Global trend**
House Crow	*Corvus splendens*	Corvidae	Passeriformes	Omn	Vc	LC	Stable
Jungle Babbler	*Turdoides striata*	Leiothrichidae		Omn	Co	LC	Stable
House Sparrow	*Passer domesticus*	Passeridae		Omn	Vc	LC	Dec.
Common Myna	*Acridotheres tristis*	Sturnidae		Omn	Vc	LC	Inc.
Jungle Myna	*Acridotheres fuscus*	Sturnidae		Omn	Fc	LC	Dec.
Rufous Treepie	*Dendrocitta vagabunda*	Corvidae		Ins	Co	LC	Stable
Red-vented Bulbul	*Pycnonotus cafer*	Pycnonotidae		Omn	Co	LC	Inc.
Asian Pied-starling	*Gracupica contra*	Sturnidae		Omn	Co	LC	Inc.
Black-hooded Oriole	*Oriolus xanthornus*	Oriolidae		Omn	Co	LC	Unknown
Oriental Magpie-robin	*Copsychus saularis*	Muscicapidae		Ins	Co	LC	Stable
Common Tailorbird	*Orthotomus sutorius*	Cisticolidae		Ins	Fc	LC	Stable
Black Drongo	*Dicrurus macrocercus*	Dicruridae		Ins	Vc	LC	Unknown
Purple Sunbird	*Cinnyris asiaticus*	Nectariniidae		Nect	Co	LC	Stable
Alexandrine Parakeet	*Psittacula eupatria*	Psittacuidae	Psittaciformes	Frug	Ra	NT	Dec.
Rose-ringed Parakeet	*Psittacula krameri*	Psittacuidae		Frug	Co	LC	Dec.

Common Name	Scientific name	Family	Order	Feeding guild	Local Status	IUCN Status	Global trend
Coppersmith Barbet	*Psilopogon haemacephala*	Megalaimidae	Piciformes	Frug	Co	LC	Inc.
Blue-throated Barbet	*Psilopogon asiaticus*	Megalaimidae		Frug	Ra	LC	Inc.
Lineated Barbet	*Psilopogon lineatus*	Megalaimidae		Frug	Fc	LC	Stable
Lesser Golden-backed Woodpecker	*Dinopium benghalense*	Picidae		Ins	Co	LC	Stable
Rufous Woodpecker	*Micropternus brachyurus*	Picidae		Ins	Fc	LC	Dec.
Fulvous-breasted Woodpecker	*Dendrocopos macei*	Picidae		Ins	Co	LC	Stable
White-throated Kingfisher	*Halcyon smyrnensis*	Alcedinidae	Coraciiformes	Car	Fc	LC	Inc.
Stork-billed Kingfisher	*Pelargopsis capensis*	Alcedinidae		Car	Ra	LC	Dec.
Common Kingfisher	*Alcedo atthis*	Alcedinidae		Car	Fc	LC	Unknown
Asian Green Bee-eater	*Merops orientalis*	Meropidae		Ins	Co	LC	Inc.
Indian Cormorant	*Phalacrocorax fuscicollis*	Phalacrocoracidae	Suliformes	Car	Ra	LC	Unknown
Little Cormorant	*Microcarbo niger*	Phalacrocoracidae		Car	Ra	LC	Unknown
Spotted Dove	*Spilopelia chinensis*	Columbidae	Columbiformes	Gran	Co	LC	Inc.
Rock Dove	*Columba livia*	Columbidae		Gran	Vc	LC	Dec.
Common Cuckoo	*Cuculus canorus*	Cuculidae	Cuculiformes	Ins	Co	LC	Dec.
Indian Spotted Eagle	*Clanga hastata*	Accipitridae	Accipitriformes	Car	Ra	VU	Dec.

We found that the distribution of species richness and abundance were over-dispersed and negatively skewed (variance > mean). Hence, two Generalized Linear Mixed Models (GLMMs) with negative binomial distribution and log-link were carried out separately considering species richness and abundance of birds as response variables against the habitat features (i.e. total number of trees, bushes, waterbodies, buildings and market) as predictor variables (fixed factors) and transect ID (as a random factor) in both the models. Prior to running the GLMMs, we tested multicollinearity between variables using variance inflation factor (VIF) method (Zuur *et al.* 2013) and only included the predictor variables with a VIF value < 5 (Montgomery & Peck 1992) to ensure that no variables were strongly correlated. Statistical tests were performed using SPSS software (ver. 20). Significance was tested at p < 0.05 and data were presented as mean±standard error.

Results

A total of 31 species of birds belonging to eight orders and 19 families were recorded during the study *(Table 1)*, of which most species belonged to the order Passeriformes (13 species) followed by the order Piciformes (6 species). Most of the recorded species were resident (96.55%). Among all avian species observed during the study, only the Indian Spotted Eagle *Clanga hastata* fall under the IUCN vulnerable (VU) category, while the remaining species are categorized as least concern (LC) species (del Hoyo *et al.* 2014). Assessment of local abundance revealed that out of 31 species recorded, five species (16.1%) were very common, 14 species (45.2%) were common, six species (19.4%) were fairly common and six species (19.4%) were rare. When this local abundance was compared with the global population trend for the species (del Hoyo *et al.* 2014), we found that two species having a globally declining trend were still very common in the study area *(Table 1)*.

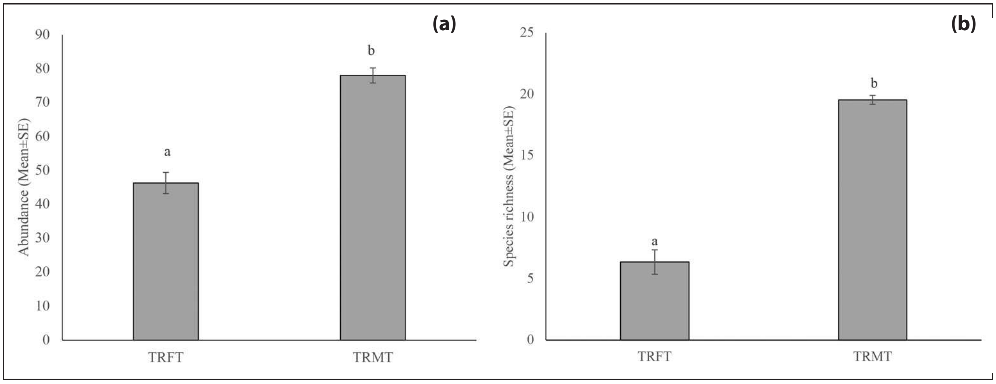

Figure 2. (a) Abundance and (b) species richness of birds in TRFT and TRMT [Columns with different letters indicate significant difference (Bonferroni post hoc tests P<0.05). Error bars indicate standard errors (SE) of means]

2. ábra A madarak (a) denzitása és (b) fajszáma a kevés (TRFT) és sok (TRMT) sok fát tartalmazó transzektek mentén. Az oszlopok magassága és a vonalak az átlagot±SE mutatják, az oszlopok fölötti eltérő betűk a szignifikáns különböző átlagot jelzik (P< 0,05, Bonferroni post hoc teszt)

Table 2. Variables in the GLMMs describing the species richness and abundance of birds in streetscapes of Kolkata, West Bengal, India

2. táblázat Az élőhelyi változók kapcsolata a transzektek mentén mért fajgazdagsággal és denzitással. A táblázat az elemzéshez használt lineáris kevert modell (GMML) eredményét mutatja

Variables	**Species richness**				**Abundance**			
	F	**df1**	**df2**	**P**	**F**	**df1**	**df2**	**P**
Number of trees	**14.485**	**1**	**90**	**0.000**	**8.081**	**1**	**90**	**0.006**
Number of bushes	1.238	1	90	0.269	2.81	1	90	0.097
Number of waterbodies	1.415	1	90	0.237	1.796	1	90	0.184
Number of markets	0.152	1	90	0.697	1.45	1	90	0.232
Number of buildings	1.312	1	90	0.255	0.051	1	90	0.822

Out of all species of birds recorded during this study, only two species (Stork-billed Kingfisher *Pelargopsis capensis* and Lineated Barbet *Psilopogon lineatus*) were found exclusively in the TRMT and 29 species (93.55%) were found in both TRFT and TRMT. We also found that the abundance of birds in TRMT (78±4.1 individuals) were significantly higher (Mann Whitney test: U=189, P=0.000) than the abundance of birds recorded from TRFT (53.74±2.5 individuals) as shown in *Figure 2a*. Similarly, *Figure 2b* shows that the species richness of TRMT (19.55±1.7 species) was also significantly higher (Mann Whitney test: U=200.5, P=0.000) than TRFT (9.5±0.8 species). GLMM further revealed that the species richness ($F_{1,90}$=14.485, P<0.05) and the abundance of birds ($F_{1,90}$=8.081, P<0.05) were positively influenced by the number of trees *(Table 2)*. However, the other land use variables (i.e. number of bushes, waterbodies, markets and buildings) neither influenced the abundance of birds nor the species richness *(Table 2)*.

Discussion

Urban areas across the globe are inhabited by many species of flora and fauna (Shwartz *et al.* 2014a, 2014b), including birds (Gatesire *et al.* 2014). Birds are often abundant in areas with suitable survival conditions (Veech *et al.* 2010) and the structural features of any habitat give important cues for birds to decide upon whether to use that particular habitat or not (Cody 1981). Greenspaces with suitable structure and floral composition favour bird communities in urban areas (Jokimäki 1999, Daniels & Kirkpatrick 2006, MacGregor-Forz *et al.* 2009) and areas with rich vegetation in the greenspaces usually sustain greater bird abundance as compared to areas with impoverished vegetation (Chace & Walsh 2006). We also found that species richness and the abundance of birds were higher in TRMT than in TRFT. Moreover, amongst various land use features, the increasing number of trees also increased the species richness and abundance of birds during the present study. Several authors found that trees in urban areas usually attract the moderately abundant species (Jokimäki 1999, Ortega-Álvarez & MacGregor-Fors 2009, MacGregor-Fors *et al.* 2010). Few others mentioned that sufficient number of greenspaces in urban areas may even support forest birds (Mortberg & Wallentias 2000, Park & Lee 2000). Again, Sandstrom *et* *al.* (2006) emphasized the importance of large trees and multi-layered vegetation for urban avian richness. Increasing tree cover provides crucial resources for the arboreal and forest birds (Ciach & Frohlich 2017).

Urban bird communities highly depend on the structure and type of vegetation (White *et al.* 2005). Abundance of bird species are positively influenced by the richness of native tree species (Chace & Walsh 2006, Paker *et al.* 2014). Particularly the native species that existed prior to urbanization are largely benefitted by the plantation of various native tree species (Bhullar & Majer 2000). As compared to exotic trees, the diversity and abundance of insects as well as other resources for birds (such as fruits, nectar etc) are often higher in native trees (White *et al.* 2005, Ikin *et al.* 2013). The indigenous species also support greater number of arthropods (Bhullar & Majer 2000) and therefore, are frequented by large number of insectivorous birds (Majer *et al.* 1994, Recher *et al.* 1996). During the present study, we also noticed several old and native trees (such as Banyan, Peepal etc.) which supported great number of birds. However, due to paucity of scientific studies, exotic tree species are arbitrarily planted along the roadside in many urban areas. Thus, implementation of effective strategies and incentives that encourage the planting of native vegetation in streetscapes and garden should be paramount (White *et al.* 2005). Protection of large indigenous trees along the roads, plantation of a greater number of native trees and retaining the existing bushes will undoubtedly be beneficial to sustain the bird communities in the urban landscape (White *et al.* 2005).

Water birds (like ducks, waders and piscivores) and other wetland associated birds (like kingfishers) are mainly benefitted by increasing water area (Yuan *et al.* 2014) as they often aggregate around such water bodies. Chamberlain *et al.* (2007) reported that the presence of waterbodies in urban areas increased avian species richness. However, only three species of kingfishers (White-throated Kingfisher *Halcyon smyrnensis*, Stork-billed Kingfisher *Pelargopsis capensis* and Common Kingfisher *Alcedo atthis*) and two species of cormorants (Indian Cormorant *Phalacrocorax fuscicollis* and Little Cormorant *Microcarbo niger*) were rarely noticed during the present study. Possibly, due to such rare presence of water birds in our study area, we did not find any influence of water bodies on the abundance and species richness of birds.

Bushes are important mainly for forest-dwelling birds and urban avoiders to thrive in the human dominated habitats (Brandt *et al.* 2013, Gopal *et al.* 2018) and increasing number of buildings have been reported to decrease species richness (Evans *et al.* 2009). Few species of urban exploiters and scavengers congregate around the markets and its adjacent garbage dumping sites (Mazumdar *et al.* 2016, 2018, 2019) and forage on the refuse as these foods are plenty and predictable. However, we did not notice any significant influence of bushes, markets and buildings on the species richness and abundance of birds.

Our findings indicate that plantation of indigenous trees along the roads might be beneficial in sustaining greater avian diversity in urban streetscapes. Particularly in urban areas of developing countries, which are rapidly losing the greenspaces due to infrastructure development, the roadside plantations might serve as important habitat for birds. Street trees in urban areas are also associated with higher property values, reduced crime rates, economic benefits (Abd Kadir & Othman 2012), as well as are known to perform various important ecological roles (Bhullar & Majer 2000). They provide manifold benefits such as absorption of GHGs, reduction of air pollution due to vehicular exhausts (Johnson 2009), watershed protection, providing shade on asphalt and concrete structures thereby, reducing the ambient air temperature (Abd Kadir & Othman 2012). However, sometimes falling of street trees lead to casualties and damage of properties, particularly after storms. Falling of large trees in urban areas often happen due to unplanned developmental activities around the root area of the trees (such as random and unplanned cutting the roots for various infrastructural modifications, higher abundance of rodents or termites around the tree roots making the root loosening the soil around the root system etc.). Plantation of appropriate roadside trees will be useful to sustain and also elevate the avian diversity in urban areas, as well as increase the aesthetic value of citizens. Empirical evidences of this research can be useful for urban planners to perceive the importance of various habitat features in urban streetscapes in sustaining the avian diversity. The managers and wildlife planners need to realize the importance of the streetscapes in conservation of urban avian diversity.

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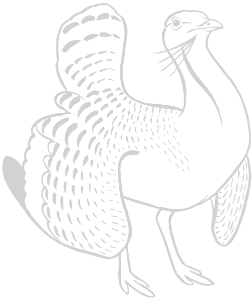

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Nesting habitat selection and challenges of conservation of the vulnerable Lesser Adjutant *Leptoptilos javanicus* (Horsfield, 1821) in the Chitwan National Park, Nepal

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Abstract The nesting ecology and conservation threats of the Lesser Adjutant *(Leptoptilos javanicus)* were studied in the Chitwan National Park, Nepal. We located nine nesting colonies during the nesting season. The number of nests was highly positively correlated with tree height, diameter at breast height and canopy cover. The uppermost canopy of the trees was the most preferred nesting place. Storks preferred to nest in compact colonies on large, widely branched trees with thin foliage cover, such as *Bombax ceiba,* and also nearby the foraging grounds such as wetlands and grasslands. Storks mostly preferred to nest in *Bombax ceiba,* but if this tree was not available, they nested in other trees, such as *Shorea robusta, Ficus racemosa* and *Terminalia alata*. During the breeding season, 180 adults, 76 nests and 88 chicks were recorded, where the highest number of chicks was recorded near the Sauraha area of the Chitwan National Park. Most of the colonies were far from human settlements, which suggest that human disturbance could be the major determinant of nesting habitat selection in this area. The wetlands nearby human settlements are either overexploited in terms of mass collection of the storks` prey species by people or disturbed highly due to presence of a large number of people. These empirical findings suggest that conservation of Lesser Adjutant mainly rely on the protection of mature *Bombax ceiba* trees and the reduction of human disturbance and of the collection of stork prey animals from foraging areas.

Keywords: Chitwan, conservation threats, Lesser Adjutant, nesting ecology, wetlands

Összefoglalás Az indiai marabu *(Leptoptilos javanicus)* költésökológiáját és a fajt veszélyeztető tényezőket tanulmányozták egy nepáli vizsgálatban, a Chitwan Nemzeti Parkban. A fészkelési időszak során 9 fészkelőtelepet találtak a területen. A fészkek száma pozitív korrelációt mutatott a fák magasságával, a mellmagasságban mért törzsátmérővel és a lombkorona kiterjedésével. A madarak számára legkedveltebb fészkelőhelynek a felső lombkoronaszint bizonyult. Jellemzően inkább tömör kolóniákban, a széles ágszerkezettel rendelkező, vékony lombozatú fákon – mint pl. a *Bombax ceiba* – illetve a táplálkozóhelyek – pl. vizes élőhelyek és gyepek – közelében fészkeltek. Preferálták ezt a fafajt, ennek hiányában azonban más fajokat választottak pl. *Shorea robusta*, *Ficus racemosa*, *Terminalia alata*. A költési szezonban 76 fészket, 180 adult egyedet és 88 fiókát számláltak, a legtöbb fiókát a Sauraha régió környékén figyelték meg. A legtöbb telep a településektől távol esett, amiből arra következtettek, hogy az emberi zavarás kiemelt hatással van a fészkelőhelyek kiválasztására a területen. A településekhez közeli vizes élőhelyek túlhasználtak a zsákmányfajok tömegei által, vagy erősen zavartak az emberi jelenlét miatt. Ezek a tapasztalatok azt feltételezik, hogy az indiai marabu megőrzése elsősorban az idős *Bombax ceiba* fák védelmével, az emberi zavarás és a zsákmányállatok táplálkozási területekről való összegyűjtésének csökkentésével lehetséges.

Kulcsszavak: Chitwan, veszélyeztető tényezők, indiai marabu, költésökológia, vizes élőhelyek

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Introduction

Lesser Adjutant *Leptoptilos javanicus* (LA) is widely distributed in the Indian subcontinent (de Silva *et al.* 2015) however, its breeding areas are mostly restricted to smaller patches compared to its non-breeding sites. The colonies of LA most likely occur in farmlands and swampy areas for foraging, however, their nests are found on trees higher than 30 m far from the foraging grounds (Karki & Thapa 2013). Therefore, tall trees with wide branches limit the distribution of nesting colonies of this species. LA is listed globally and nationally as vulnerable (Inskipp et al. 2016, BirdLife International 2017), because it has a small and declining population owing to habitat loss and degradation, hunting and disturbance (BirdLife International 2017). However, this species has not yet been listed as a nationally protected bird species by the National Parks and Wildlife Conservation Act of 1973 in Nepal (DNPWC 2020b). The LA is common in southern lowland Nepal, but it has been recorded in larger numbers in and around protected areas, such as Chitwan National Park (CNP), Koshi Tappu Wildlife Reserve (KTWR) and a few in the western Terai regions (Baral 2005, Poudyal & Nepal 2010, Karki & Thapa 2013, Baral *et al.* 2020). LA becomes mature for breeding around three to five years of age and pairs can be seen only during the breeding season (July–October) (Baral 2005, Sundar *et al.* 2016, 2019).

In the lowlands, croplands dominate (mainly paddy) the most of the landscape as compared to the foraging habitats available inside the protected areas. Forested habitats along with such areas provide a wide array of foraging grounds and nesting sites for wetland-dependent bird species. For example, several water birds such as herons, ibises and storks, show strong preferences for wetlands relative to paddy fields as foraging and breeding habitats, particularly when conditions such as water depth and prey availability are favourable (Fidorra *et al.* 2016). Generally, population dynamics and foraging behaviour of a colonial nesting species like LA show strong relationships with the quality of natural wetland habitats (Frederick *et al.* 2009, Sundar *et al.* 2016), as well as its changes during the nesting seasons (Karki & Thapa 2013). The nesting season and the ecology of water birds depends on prey availability and threats caused by human activities, such as alternation of wetlands or excessive use of pesticides in croplands (Tozer *et al.* 2010, Bennett *et al.* 2018).

Empirical research on LA including use of and dependence upon agricultural landscapes is quite important, since such habitats have been modified by the modernization of agriculture (Adhikari *et al.* 2019, Choudhary 2019, Lamsal *et al.* 2019). Therefore, it is necessary to test such relationship between vulnerable water birds like LA and nesting habitat features in human-dominated landscapes. The studies on changes in cropping patterns to a drier monsoonal crop (e.g., hybrid varieties of maize for high production), or reductions in wetlands and availability of taller and wide-branched trees like *Bombax ceiba* found nearby wetlands and farmlands are necessary for the conservation of such species (Baral 2005, Karki & Thapa 2013). Therefore, this study was designed to fill the gap in understanding of the nesting ecology and factors affecting nesting habitat selection of LA in selected areas of CNP. We examined i) how vegetation structure and habitat parameters associated with nesting colonies, ii) tested whether the nest trees differed from non-nest trees with respect to their structure, and iii) what features of the trees and surrounding environment were important in determining the number of LA nests in a colony.

Materials and Methods

Study Area

The Chitwan valley lies in the lowlands of the southern central part of Nepal, which has one of the greatest variety and abundance of wildlife in Asia. The intensive study area located in the core area of the Chitwan National Park (CNP) and Barandabhar Corridor Forest

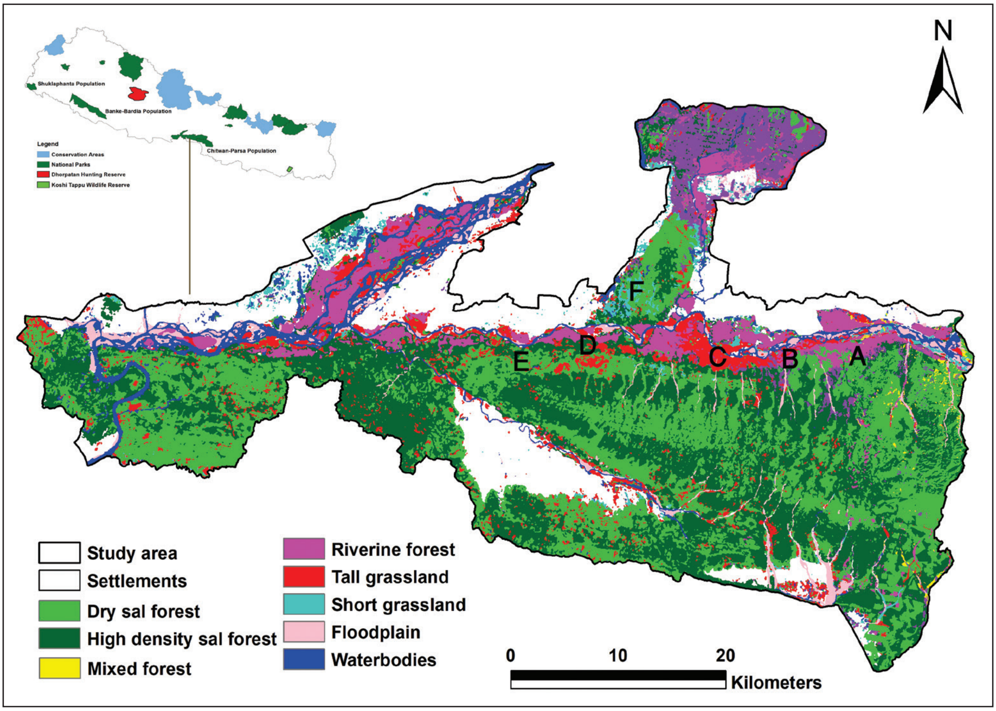

Figure 1. Map of the study area including land cover types and location (A-F) of nesting colonies of LA. Khagendramalli area (A), Old Padampur area (B), Sauraha area (C), Belsar-Dumaria area (D), Ghatgain area (E) and Barandabhar Corridor Forest– bufferzone part of CNP (Beeshazari Lake and associated areas) (F)

1. ábra A vizsgálati terület térképe, beleértve az indiai marabu fészkelőtelepeinek elhelyezkedését (A–F) és az ottani felszínborítást. Khagendramalli régió (A), Old Padampur régió (B), Sauraha régió (C), Belsar-Dumaria régió (D), Ghatgain régió (E) és Barandabhar ökológiai folyosó – nemzeti parki pufferzóna (Beeshazari-tó és kapcsolódó területei) (F)

(BCF), buffer zone part of CNP. CNP *(Figure 1)* has a core area of 952.63 km^2 and a 729.37 km^2 buffer zone area, comprising mainly forests (80%), including *Shorea* forest, riverine forests and mixed hardwood forests. Besides, there are grasslands (12%), exposed surfaces (5%) and water bodies (3%) (Thapa 2011, DNPWC 2020a). These grasslands (both tall and short) are also a part of the Terai Duar Savana and Grasslands, a Global 200 ecoregion (Wikramanayake *et al.* 2002). The riverine forest is distributed along the river courses with the large tracks of *Bombax ceiba* and Khair-Sissoo forest (Bhattarai & Kindlmann 2012).

The major wetland habitats of the park are the rivers (e.g. Rapti, Budirapti, Khageri), streams, lakes (e.g. Beeshazari, Batulpokhari, Kumal, Tikauli, Nandan, Patna, Tamor, Lami lake), marshlands along the forest patches, seasonal ponds and paddy fields. The CNP provides habitat for more than 68 species of mammals, 544 species of birds, 56 species of reptiles and amphibians and 126 species of fish (CNP 2020). It is also a pristine habitat for migratory birds such as Black Stork *(Ciconia nigra)* and Woolly-necked Stork *(Ciconia episcopus)*. These birds use this area as a stop-off point (stepping stone) on the way to their ultimate destination (Bhattarai & Kindlmann 2012a, Inskipp *et al.* 2016, BirdLife International 2017).

Field Study and Data Collection

The survey of nesting colonies and threats to conservation of LA was conducted during a breeding season between August 2018 and March 2019. The population count of LA was taken only during the post-breeding season to focus on the maximum records (January-February), which was used for further analysis. We searched for LA and their nesting colonies in the villages and forests along the bird survey routes. The survey routes were located along roads, tracks, river banks and at the periphery of lakes. The nesting colonies were also identified by asking local farmers and nature guides. In each nesting colony, we identified the nesting trees and counted the number and position of nest(s) including presence of chicks in each tree directly in the early morning and evening time, expecting that all birds were present on their nests. Nests were categorized as active or apparently occupied if there was presence of young/chicks or at least one adult in the nest (Bibby *et al.* 2000). We also checked whether the chicks were fledged or not. For determining the use of nesting habitat and tree, we measured dimensions of tree species, including height of the tree from the ground, diameter at breast height (DBH) and canopy cover area (CCA). The height of the tree and height of the nests were estimated by using Bushnell Range Finder. Canopy cover by each tree species was estimated by measuring canopy spread from the base of the tree trunk in four directions at right angles to each other. Later, the average canopy cover was estimated as the average of the four radii. Besides, we also identified and measured the dimensions of the nearest non-nest tree of greater than 10 m in height within 20 m from the base of the nest tree. Likewise, we estimated the nearest distance between nesting trees and the dominant vegetation around each nesting tree.

Furthermore, we also investigated the factors affecting nesting habitat selection of LA such as the distances of other habitat parameters, nearest foraging areas (wetlands, grasslands and croplands), nearest forests, nearest human settlements, nearest road including number of livestock, number of people collecting forest and wetland products and number of tourists from the nest tree. We considered nearest forest as either a thick, mixed plantation, often found in villages, or a natural patch of thick vegetation. The nearest foraging grounds were short grasslands, rivers, ponds, lakes or marshes including crop fields.

Separate two sample t-tests for equal means were applied to test the significance of differences between nest and non-nest trees in height, DBH and canopy area, after checking for normality using Shapiro test. The strength of associations between the number of nests and tree structure and also between the number of nests and habitat and disturbance parameters were measured (Lens & Van Dongen 2000) by linear regression. The auto correlated variables were removed from the analysis after testing Durbin Watson test (Durbin & Watson 1971). No autocorrelation was detected by checking the values that lie near 2 (1.5 to 2.5). All the analyses were performed in PAST program (Hammer *et al.* 2001) and R version 4.0.0. (R Core Team 2020).

Results

Nesting Habitat Selection

Nine nesting colonies in six locations *(Table 1)* with a total of 76 active nests in 20 trees were recorded. Most colonies were in the riverine forests and the rest were in the *Shorea* forests. *Bombax ceiba* trees in riverine forest possessed the highest number of nesting colonies and nests *(Table 1, 2)*. The number and height of the nests were higher in taller trees with larger DBH and canopy cover area at all the sites. Khagendramalli and Ghatgain colonies were nearby village forest borders compared to other colonies. However, Sauraha and Belsar-Dumaria colonies were far from villages. The highest number of nests were recorded from Dudhaura, Tick plantation site, one and two numbered bridge sites of Sauraha area, while the least number of nests were recorded in the Khagendramalli area having the highest human intervention *(Table 2)*.

Table 1. Locations of the nesting colonies, number of nests and the attributes/characteristics of the nesting trees of Lesser Adjutant in the CNP

1. táblázat Az indiai marabu fészkelőtelepeinek elhelyezkedése, a fészkek száma és a fészkelésre használt fák jellemzői a Chitwan Nemzeti Park területén

Location of Colony	No. of Nest Trees	No. of Nests	Height of Tree (m±SD)	Height of Nest (m±SD)	DBH (m±SD)	Canopy Cover Area (m^2±SD)
Khagendramalli area (A)	2	4	29.50±0.71	27.50±0.71	1.65±0.07	328.0±73.54
Old Padampur area (B)	3	12	31.33±4.16	27.33±3.21	2.37±0.50	587.0±165.30
Sauraha area (C)	6	28	33.33±3.20	26.00±3.58	2.65±0.55	662.17±111.69
Belsar-Dumaria area (D)	4	16	32.75±3.86	26.75±3.77	2.10±0.74	665.75±123.79
Ghatgain area (E)	2	7	30.50±9.19	26.50±4.95	1.90±1.13	556.50±342.95
Barandabhar Corridor Forest (F)	3	9	29.67±3.21	26.33±4.73	1.80±0.30	335.0±35.04

Table 2. Characteristics of the nesting trees (in Mean±SD) used by the Lesser Adjutant in a breeding season (2018–2019)

2. táblázat Az indiai marabu által fészkelésre használt fák jellemzői (átlag±SD) a költési szezonban (2018–2019)

Tree Species	**Number of Trees**	**No. of Nest**	**Height of Tree**	**Height of Nest**	**DBH**	**Canopy Cover Area**
Bombax ceiba (Simal)	13	4.54±1.8	33.4±3.3	26.9±3.4	2.48±0.56	676.8±104.5
Ficus racemosa (Dumri)	1	1.0	24.0	23.0	1.1	314.0
Shorea robusta (Sal)	4	2.5±0.6	28.5±2.1	26.0±3.7	1.77±0.3	355.7±47.6
Terminalia alata (Saj)	2	3.0±1.4	31.0±1.4	28.0±0.7	1.70±0.14	322.5±65.8

During a breeding season in 2016–2017, LA used twenty individual trees of four species for nesting *(Table 2)*. Storks used the same tree for nesting before and during the breeding seasons, as there was only increase in the number of nests. LA mostly used *Bombax ceiba* (Simal) trees for nesting compared to other trees *(Table 2)*. There were also 20 non-nest trees of six species selected and measured for comparison. Among them, four species (*Bombax ceiba, Ficus racemosa, Shorea robusta* and *Terminalia alata*) were the most frequent used as nesting trees. There was significant difference between nesting and non-nesting trees in terms of height (t=11.57, P=0.0001) diameter at breast height (t=5.89, P=0.0001) and canopy cover area (t=5.08, P=0.0002).

In the study area, LA started nesting during the first half of September. During this pre-breeding period (September–November), a total of 30 nests and no chicks of LA were

Figure 2. Nests of Lesser Adjutant on *Bombax ceiba* tree in the Chitwan National Park

2. ábra Indiai marabu fészkek *Bombax ceiba* fán a Chitwan Nemzeti Parkban

Table 3. Number of nests, adults of LA and number of chicks during a breeding season
3. táblázat Az indiai marabu fészkek száma, az adult egyedszám és a fiókaszám a költési szezonban

Location	No. of nests	Adults	Chicks
Khagendramalli area (A)	4	37	6
Old Padampur area (B)	12	21	9
Sauraha area (C)	28	54	43
Belsar-Dumaria area (D)	16	31	21
Ghatgain area (E)	7	8	5
Barandabhar Corridor Forest (F)	9	29	4
Total	76	180	88

recorded. The highest number of nests were reported in Sauraha area and the lowest in Barandabhar Corridor Forest (Beeshazari and associated areas). However, these numbers were increased during the breeding season (December–February). A total of 180 adults, 76 nests and 88 chicks were recorded in the breeding season. No chicks fledged from the nest during this period; however, this did not mean that the nesting attempts failed, which was not monitored. There were 4 nests with chicks in Khagendramalli area, 6 in Old Padampur area, 23 in Sauraha area, 12 in Belsar-Dumaria area, 3 in Ghatgain area and 3 nests with chicks in Barandabhar Corridor Forest *(Figure 2, Table 3)*. The highest number of chicks was reported in Sauraha area and the lowest number of chicks in Barandabhar Corridor Forest.

Figure 3. Paddy fields are also the major foraging areas for Lesser Adjutant in the study area
3. ábra Az indiai marabu számára a rizsföldek jelentik a fő táplálkozóhelyeket a vizsgálati területen

Table 4. Linear regression showing effects of DBH, height and canopy cover area of nesting tree species on number of nests in the study area

4. táblázat Lineáris regresszió, amely a fészkelésre használt fafajok mellmagassági törzsátmérőjének, magasságának és a lombkorona kiterjedésének a fészkek számára gyakorolt hatását mutatja a vizsgálati területen

Model parameters	Durbin–Watson	Unstandardized Coefficients		Standardized Coefficients	R²	t value	Pr(>|t|)
		B	Std. error	Beta			
DBH	2.204	2.165	0.490	0.721	0.521	4.417	<0.0001
HoT	2.131	0.119	0.064	0.402	0.161	1.861	0.079
CCA	2.333	0.007	0.003	0.519	0.270	2.579	0.019

Durbin-Watson test was performed to test the autocorrelation and found that there was no autocorrelation as the values lie near 2 (1.5 to 2.5). The strength of the relationship between various parameters of nesting tree species and number of nests were measured by performing linear regression. The result showed that the number of nests of LA significantly positively associated with the height, DBH and canopy cover area of tree species *(Figure 3, Table 4)*.

The present study showed that DBH and canopy cover of nesting tree species were the major determinants of the preference of nesting trees for LA, with high number of nests present in those trees with high DBH values and canopy cover area.

Factors Affecting Nesting of Storks

Availability of foraging area: Our results indicated higher number of nests nearby foraging areas including rivers, streams, lakes, ponds and paddy fields (farmlands) *(Figure 3)*. The number of nests was negatively correlated with the distance to the nearest wetlands and foraging areas (Durbin-Watson=1.174, R^2=0.397, F=11.851, P=0.003) *(Figure 4)*.

Habitat Disturbance and Destruction: Human and livestock encroachment inside the forest mainly in grasslands and marshy lands was high that could change the population and behaviour of grassland-dependent birds, such as storks, by decreasing the size of feeding and breeding habitats. The variables, for which the estimated values did not lie near 2 (1.5 to 2.5), were considered as correlated and removed from the analysis.

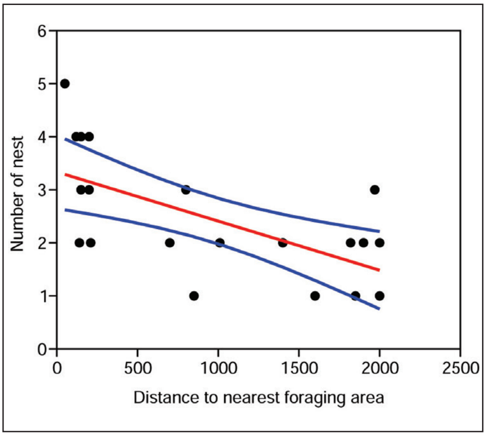

Figure 4. Linear regression between number of nests of LA and distance to nearest foraging areas (paddy fields, wetlands, grasslands)

4. ábra Lineáris regresszió az indiai marabu fészkek száma és a legközelebbi táplálkozóhelyek (rizsföldek, vizes élőhelyek, gyepek) között távolság között

Table 5. Linear regression showing effects of disturbance variables (nearest village distance-NVD, nearest road distance-NRD), number of people, livestock and tourists on the number of nests (NoN) and population of LA in the study area

5. táblázat Lineáris regresszió, amely a zavaró változók (legközelebbi település távolsága – NVD, legközelebbi úttávolság – NRD), az emberek számának, a haszonállatok számának és a turisták számának hatását mutatja az indiai marabu fészkek számára (NoN) és a faj populációjára a vizsgálati területen

Model parameters	Durbin–Watson	Unstandardized Coefficients		Standardized Coefficients	R^2	t value	Pr(>|t|)
		B	Std. error	Beta			
With number of nests of LA							
NVD	1.516	0.000	0.000	0.485	0.236	2.351	0.030
No. of people	2.235	-0.03	0.005	-0.786	0.618	-5.395	<0.0001
No. of livestock	1.523	-0.035	0.009	-0.662	0.438	-3.748	0.001
No. of tourists	2.184	-0.024	0.029	-0.190	0.036	-0.822	0.422
With population of LA							
NRD	1.561	0.020	0.007	0.590	0.349	3.104	0.006
NVD	1.569	0.003	0.001	0.702	0.493	4.187	0.001

Significant negative relationship was between the number of nests of LA and the number of people and livestock. There was marginally significant relation with the distance to village. There was no significant relationship between the number of nests and the number of tourists *(Table 5)*. Regarding the population of LA, there was autocorrelation with most of the variables except nearest village distance (NVD) and nearest village distance (NRD). The population of LA showed significant positive correlation with NRD and NVD.

Furthermore, our field observation found that habitat destruction and disturbances caused by human activities and eutrophication were the major threats to them. Per day, we found on average 880 people collecting grass, fodder and firewood; 219 people fishing, collecting molluscs and other wetlands products; 292 foreign tourists and 712 individuals of livestock in and around the wetlands of the study area. Apart from the fishing community, of other people collecting wetland products, 86 were in the Beeshazari and associated lake areas, 36 in the Rapti River, 17 in the Budhi Rapti River, 52 in the Khageri River and 28 in other wetlands inside the forest. Among them, almost all used to collect wetland species such as fishes and molluscs. Some of them, mostly the young ones, involved in the collection of eggs and young birds in the study area, mainly in the Beeshazari lake area and Khageri riversides. In addition, the dense mat of water hyacinth *(Eichhornia crassipes)* and southern cut grass *(Leersia hexandra)* in the Beeshazari and associated lakes may trap and kill diving water birds. Because of the dense growth of the water hyacinth, most of the wetlands (mainly lakes and ponds) resembled grasslands. The water level was very low or almost dry in the associated lakes of Beeshazari (e.g. Shorahazar and Satrahazar Lakes), Patna Lake, Nandan lake and other small wetlands inside the forest.

Discussion

The present study of the nesting habitat selection of and threats to LA in the Chitwan National Park showed that there were nine nesting colonies and most of them were far from the human-disturbed areas, i.e. human settlements. Most of the colonies were in the riverine forests interspersed with grasslands. LA mostly built their nests in *Bombax ceiba* trees. This tree is generally bigger and taller than other tree species. A similar result was also obtained by Karki and Thapa (2013) in eastern lowland Nepal. Our results revealed that nest trees were found to be larger and significantly larger in height, DBH and canopy cover as compared to the nearest non-nest trees. Likewise, the number of nests in a tree significantly correlated with tree size (height, DBH and canopy cover area). These results suggest that LA selects taller and bigger trees for nesting. Similar results were obtained by Baral (2005) for LA and other similar species, such Greater Adjutant *Leptoptilos dubius* (Singha *et al.* 2002, Sundar *et al.* 2016, Barman & Sharma 2020) and Asian Openbill *Anastomus oscitans* (Sundar *et al.* 2016, Zainul-Abidin *et al.* 2017). The larger bird species mostly preferred to nest in taller (Burger 1979) and widely branched trees. In most parts of the study area, we found LA nests in compact colonies. The nearest nest tree distance shows the compact nature of LA colonies. A similar result was also reported by Pomeroy (1977) and Sundar *et al.* (2016); therefore, such compactness is possible only where sufficient suitable trees are available close together.

The height of the nesting trees varied among nesting colonies, most of the nests being on the top canopy of relatively large and tall trees, which is a common pattern in most of the water birds (Burger 1979, Minias & Kaczmarek 2013, Koju *et al.* 2020). Besides, some birds may nest at the top to receive more solar radiation that may affect nest temperature and thus, the amount of incubation required (Martin & Roper 1988, Slagsvold & Wiebe 2017). This is also true particularly for the Greater Adjutant, as it breeds in winter (Chowdhury & Sourav 2012, Slagsvold & Wiebe 2017). LA built their nests with large platform, and also preferred trees with sparse foliage cover (e.g. *Bombax ceiba*) at the nest site to make easy access for arrival and departure, similar to that of Greater Adjutant (Mandal & Saikia 2013). Therefore, trees with horizontal branches or branches slightly inclined parallel to the ground (e.g. not like ‘Y’ fork) were the most preferred tree for LA. Availability of wetlands and change in cropping patters in lowland Nepal was the major determinant of provisioning time for LA. However, in our study area, most of the nesting colonies of LA located far from human settlements and croplands (Baral 2005, Karki & Thapa 2013).

Nesting activities of LA depended upon various factors, such as availability of foraging grounds, nesting trees and comparatively less disturbed areas. The start of breeding season of LA was found to be later (August/September) compared to the eastern part of Nepal (July/August) (Baral 2005, Allay 2009, Karki & Thapa 2013). Breeding of LA was found to be more successful in the core area of CNP as compared to the Barandabhar Corridor Forest. Nests with chicks were reported only in the southern part of Barandabhar Corridor Forest close to the Rapti River and core area of CNP. However, there was no record of nests with chicks in and around the Beeshazari and associated areas despite having good foraging grounds. Our recent observations noticed that there were no nests in the Barandabhar

Corridor Forest in 2020. It showed the shifting tendency in nesting of LA. In contrary to the argument of Beaver *et al.* (1980) that availability of suitable tree species influences the dispersion of nests more than other factors, such as social and human disturbances. There were very few *Bombax ceiba* trees in riverine forest of Barandabhar Corridor Forest as compared to CNP (Thapa 2011, Bhattarai & Kindlmann 2012). Sauraha area possessed the highest number of nests including chicks and adults.

The study found the highest number of nests in areas that were less disturbed by human activities, such as people presence and livestock grazing. This study suggests that human disturbance limits the location, compactness and number of nesting colonies in the CNP and associated areas (Bhattarai & Kindlmann 2012, Bhattarai & Kindlmann 2013). However, in the case of Greater Adjutant colonies, both the availability of suitable nesting trees and social interactions determine the compactness of nesting colonies (Ali *et al.* 1987, Singha *et al.* 2002). Earlier studies of Datta and Pal (1993) and Sundar *et al.* (2016) reported that human disturbance caused the mortality of nestlings of Asian Openbill. A similar scenario might be true for the human-disturbed areas of the CNP and BCF. Unlike other studies (Pomeroy 1977), we did not record felling of trees by local people except a natural felling of *Bombax ceiba*, common in the CNP during the stormy season (April, May). The nearest road from the nesting colonies had very less impact on the occurrence of nests, because most of these roads were part of the road networks inside the park (e.g. firelines) and used mostly by tourist vehicles and park monitoring for security.

This study found that LA nesting colonies mostly located within 3 km of foraging areas. It has been considered that the closer distance to the foraging ground enables the storks to increase the number of foraging trips to feed the nestlings. In the study area, the foraging grounds of LA were vulnerable due to presence of people for collection of prey species (molluscs and fishes), a common practice in lowland Nepal (Baral 2005). Fishing communities, such as Tharu, Bote, Darai and Majhi people, are main inhabitants nearby the water sources or forests and highly dependent on the forests and wetlands, a common practice in rural areas (Baral 2005). In contrast, these people mostly visit wetlands of the CNP and adjoining areas during the dry winter season (i.e. nesting season of LA) compared to the rainy season. Wetlands become less suitable for LA due to increased human activities during winter season (Sundar *et al.* 2016). The conservation of LA could be successful if we protect large *Bombax ceiba* trees, minimizing human disturbance including collection of prey species, and raising awareness to reduce human activities harmful to LA. The findings of this research also highlight the lack of empirical research in nesting ecology of LA, including use and dependence upon human-dominated agricultural landscapes, such as paddy fields.

Conclusion

Understandings of nesting ecology and conservation challenges are crucial for management and conservation of threatened bird species like the LA. This study found that the number of nests of storks was highly positively correlated with tree height, diameter at breast height and canopy cover of the trees. LA mostly preferred the uppermost canopy of the trees for nesting. The nests were found in compact colonies on large, widely branched trees with thin foliage cover such as *Bombax ceiba.* In the absence of *Bombax ceiba*, they built nest on other trees with similar dimension e.g. *Shorea robusta, Ficus racemosa* and *Terminalia alata*. Most of the nesting colonies were recorded nearby foraging grounds. There were a total of 180 adults, 76 nests and 88 chicks recorded in the breeding season, in which Sauraha area possessed the highest number of adults and chicks. Most of the nesting colonies were far from human settlements, suggesting that human disturbance could play a major role in nesting habitat selection. These results imply that nesting success of LA mainly rely on the protection of *Bombax ceiba* trees and their long-term conservation requires minimal human disturbance and sustainable utilization of wetland products, including collection of prey species of storks by fishing communities.

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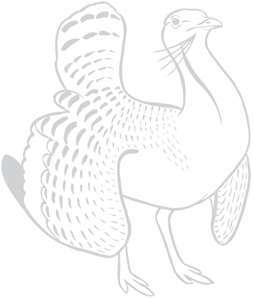

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Conservation management rules for reconstructing Moluccan Scrubfowl *(Eulipoa wallacei)* egg-laying habitats

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Abstract This research focused on the efforts of indigenous people invested into the reconstruction of damaged Moluccan Scrubfowl *(Eulipoa wallacei)* egg-laying habitats, as well as, on the ways how the current conditions of the landscapes are conserved by indigenous people. This is a qualitative and quantitative study that used a combination of observation and interview methods. We also used descriptive analysis and spatial analysis including remote sensing techniques. The results showed that the abrasion process that destroyed the Moluccan Scrubfowl egg-laying habitat left a remaining sandbar with an area of 1,161 m^2, or about 17% of the area of the initial sandbar. Even though the habitat has not fully recovered, Moluccan Scrubfowls still lay their eggs there. The details of the reconstruction activities carried out by indigenous people are as follows: making embankments, adding sand to the eroded area, replanting supporting coastal vegetation, and making breeding sites. In addition, efforts were also made to restore the surrounding support areas that were also damaged. The activities carried out were as follows: replantation of coral reefs, turtle breeding, nurseries and mangrove planting, nurseries of other plant species such as cloves and nutmegs, picking up trash along the coast, and early education for children in how to be environmentally conscious.

Keywords: Moluccan Scrubfowl, degradation, habitat, abrasion, conservation, indigenous people

Összefoglalás A jelen vizsgálat a helyi lakosok a maluku-szigeteki ásótyúk *(Eulipoa wallacei)* rongálódott tojásrakó helyeinek rekonstrukciója érdekében tett erőfeszítéseivel foglalkozik, valamint azzal, hogy a tájkép jelen állapotát hogyan védelmezik ezek a törzsek. Ezen tanulmány mind kvalitatív, mind kvantitatív megközelítéseket alkalmaz, kombinálva a megfigyeléses és interjúztató adatgyűjtést. Emellett leíró statisztikai értékelést, valamint távérzékelési eljárásokat magában foglaló térbeli elemzéseket is végeztünk. Eredményeink alapján a vizsgált faj tojásrakó élőhelyeit tönkretevő abráziós folyamat egy 1,161 m^2 kiterjedésű homokbuckát hagyott csak érintetlenül, ami az eredeti élőhelynek 17%-a. Bár az élőhely még nem állt helyre, az ásótyúkok továbbra is raknak itt tojást. A helyi bennszülöttek a következő élőhelyrekonstrukciós tevékenységeket végezték: gátépítés, homokrahordás, a homokszerkezetet stabilizáló parti növényzet újratelepítése, és fészkelő helyek készítése. Ezen felül a környező, stabilitást adó, de rongálódott élőhelyek rekonstrukciójára is sor került: korallzátonyok újratelepítése, tengeri teknősök szaporítása, teknősnevelés és mangrove-ültetés, mirtuszfélék és szerecsendió ültetése, szemétszedés a parton, és környezeti nevelés.

Kulcsszavak: maluku-szigeteki ásótyúk, degradáció, élőhely, abrázió, természetvédelem, helyi lakosok

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Introduction

"Conservation" is a term that refers to the acts of protecting, preserving, and sustainably using natural resources. Furthermore, conservation is a form of natural resource allocation that is carried out optimally across different generations (Randall 1981, 2007), which relates to the principle that natural resources must remain available to future generations. In other words, the current generation does not have the full right to control or use all available natural resources because those must be left for future generations. Conservation also involves the management of the biosphere, which takes into account the ecological balance of the ecosystem. In addition, conservation entails active management of the biosphere with the aims of maintaining maximum species diversity and genetic diversity within a species, including the maintenance of biosphere functions such as ecosystem functions and biogeochemical cycles (Allaby 2010). Based on this, there are several important points that must be considered in conservation: natural resources; inheritance by the next generation; and the balance of ecosystems, biosphere, and species.

Related to these points, various conservation adaptation models and approaches emerged. Some of them are social community approaches, regional approaches, approaches to protecting forests and water resources, approaches for the purpose of pre-disaster actions, cultural approaches, approaches to maintaining germ plasm and genetic diversity, and many more. Conservation involves not just using one type of approach but combining various types of them. In order to combine several of those approaches, then, a species-based approach combined with local wisdom-based area conservation was used. Species-based conservation means conservation efforts with the aim of saving and protecting certain animal or plant species. In this approach, the related terms include "umbrella species," "flagship species," and "keystone species."

An umbrella species is a species whose distribution or range is broad, so that it covers a significant area (Roberge & Angelstam 2004); birds and several types of mammal that are classified as high-level vertebrate species are examples of umbrella species (Chase *et al.* 2000, Suter *et al.* 2002). Flagship species are iconic and characterize a particular area; such species are ambassador species that are often used as tourist attractions or icons to raise conservation funds, and they symbolize a landscape's habitat (Bowen-Jones & Entwistle 2002, Walpole & Leader-Williams 2002). Keystone species are species that play an important role in the structure, function, and productivity of an ecosystem. If this species is lost, it will cause significant changes in the biological structure of the ecosystem; therefore, conserving this species will protect the structure and function of wider habitats (Mills *et al.* 1993, Libralato *et al.* 2006).

Based on the various types of species-based approaches, their main similarity is the goal, i.e. habitat protection. This matter means protecting the region as their homes will automatically save the organisms that live there (Shogren 1998). So, it is essential to form an effective habitat rescue effort to have a broad impact on the region's conservation. Because these animal and plant species cannot automatically save their habitats, the most critical role is top-predators or super-predators, namely humans (Darimont *et al.* 2015, Smith *et al.* 2017). There is much approach to encounter the damaged habitat, but humans are still the leading role in conservation. Thus, the territorial or habitat approach must be implemented with human rules, and these rules must be following the rules of conservation. Therefore people who lived in ancient times created local wisdom as a rule to maintain habitats. Maintaining a habitat entails protecting all species that live in it.

Moluccan Scrubfowl conservation

Moluccan Scrubfowl *(Eulipoa wallacei)* is one of the endemic bird species found in some of the islands in Maluku (Coates *et al.* 1997, White 1998). The bird was intensively studied for several years near Kailolo Village (Heij 1995, 2001, 2005, Rompas & Moeliker 1997), and successfully reintroduced in Haruku Village (Heij 2005a, Heij 2005b), and then, the rate of successful reproduction and other habitat factors that are still not widely known related to their activities were continuously studied (Saiya 2013, Verboom & Heij 2016, Verboom *et al.* 2017).

The International Union for Conservation and Nature lists its status as vulnerable to extinction. The trend of Moluccan Scrubfowl population growth shows a declining pattern from year to year. One of the locations in Maluku where Moluccan Scrubfowl can be found is Haruku village, Haruku Island, Maluku Province. The village has sandy beach structures and ramps that make a suitable nesting ground for Moluccan Scrubfowls. This area is an important research area and breeding site of Moluccan Scrubfowl that are guarded and maintained by the *kewang* of Haruku village.

The *kewang* are the guardians of the environment who are raised based on customary village rules (Zerner 1994, Harkes & Novaczek 2000). In general, every village in Maluku has *kewang*, who are also referred to as rangers. The task of the *kewang* is to maintain and regulate the use and protection of natural resources in the sea and on the land (Batiran & Salim 2020). They employ customary regulations known as *sasi*, which are ordinances or prohibitions related to certain natural resources. They are part of the efforts invested to preserve the population in order to maintain the quality of biological resources (Zerner 1994, Libralato *et al.* 2006) such as animals and plants. *Sasi* are a tradition that has been carried out for generations by the people of Maluku.

The Moluccan Scrubfowl egg-laying habitat is located at the river estuary sandbar, bordering the sea. However, in recent years, the existence of the sandy beach continued to be threatened. It not only reduces the volume of sand on the beach but also washes away a lot of Moluccan Scrubfowl eggs, diminishing the population and reducing the number of breeding birds.

If this process is left unattended without any recovery effort, it will eventually eliminate the entire egg-laying habitat of Moluccan Scrubfowl, which loss will also affect the population of the species. At this point, the active role of indigenous people is significant in controlling the abrasion and preventing the loss of the entire habitat. Kewang Haruku, which is supported by the indigenous people, took the first initiative to save the habitat, which was then welcomed by several researchers, who have conducted research at the location. This was also recognized by a former minister of the environment of the Republic of Indonesia, who said that "We believe by enabling nature, man [is] enabling himself" (Salim 1982).

The importance of the species' existence in its habitat

Efforts to save habitats are a reasonable first step to save a species, because the sustainability of a species is closely related to the sustainability of its dwelling place, i.e. its habitat, which is an ecosystem unit with the species that live therein. All animals can only live in an area if basic natural resources are available, i.e. food sources, water sources, and shelter; they can adapt to extreme climatic conditions that occur at any time and can even defend and protect themselves from predators (Morrison *et al.* 1999). This is contrary to human existence, which has a high adaptability so that changes in habitat such as land conversion will not easily interfere with the existence and endurance of humans in an area. This is the difference in vulnerability between animals and humans, which is seen ecologically. For this reason, in an effort to reconstruct a damaged or threatened habitat, all elements needed by the animal that should be protected must be taken into account in the initial planning stage.

However, it is true that extinctions occur as a result of natural selection. This is consistent with Darwin's theory of evolution that individuals who can survive or adapt well will continue to survive, while those who cannot adapt will go extinct, so it can be seen that natural selection will determine which species continue to exist (Darwin & Wallace 1858, Williams 2008).

However, if we look at the rate of animal extinction in the past few decades, it can be seen that human treatment of ecosystems has accelerated animal extinction (Wright 1990, Vitousek *et al.* 1997, Brashares *et al.* 2001, Ceballos *et al.* 2015). In addition, another factor in the loss of an animal species is related to the change in its trophic position. This also affects the balance of the ecosystem, because a role is lost, and the interactions between the various components of the ecosystem are disrupted (Nilsson & Grelsson 1995, Ives & Carpenter 2007). In this study, we focus on indigenous people's efforts to reconstruct the damaged Moluccan Scrubfowl egg-laying habitat, as well as, how the current condition of the landscape is being conserved by them.

Methods

This research took place on the coast of Haruku Village, Haruku Island, Central Maluku Regency, Maluku Islands, Indonesia *(Figure 1)*. This location is protected by the indigenous people in Haruku Village. This is because, for a few decades, many Moluccan Scrubfowl have come to this coastal area to lay eggs, and since then, the people have really taken care of the area. In fact, many studies by local and international researchers have been conducted in this area. The area takes the form of a sandbar stretching up to an estuary, with dominant vegetation in the form of nipa palm *(Nypah fruticans)*, sago *(Metroxylon sagoo)* and coast cottonwood *(Hibiscus tiliaceus)*. The observation period of this study began before the abrasion disaster occurred in 2009 and continued until the end of 2019 and the beginning of 2020. We used a time series research design, which enabled the reconstruction of the location based on regular observations and monitoring by the researchers.

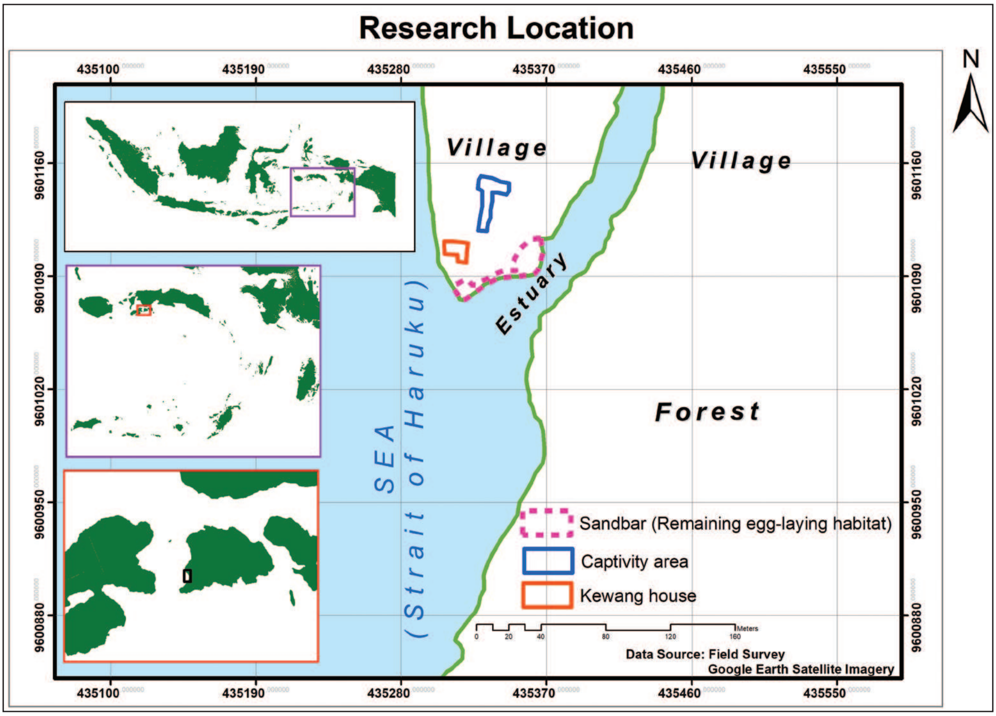


Figure 1. Map of the location (Drawings: H. G. Saiya. Modified from Saiya *et al.* 2016)
1. ábra A vizsgált terület elhelyezkedése (ábrák: H. G. Saiya. Saiya *et al.* 2016 alapján, módosítva)

The observations focused on habitat abrasion, savable areas, and people's responses to the occurrence of abrasion. The type of observation carried out was participatory observation, which involved living among indigenous people over a certain period where the researcher could record the responses of indigenous people and could jointly work with them. Furthermore, we used an open interview system, including questions on the knowledge of the Moluccan Scrubfowl and on the conservation efforts that have been carried out, the abrasion disasters, and the habitat reconstruction efforts of the people. The selected key informants were the *kewang*, representatives of the customary *adat* government in the village, and people, who participated in reconstruction of the habitat.

The data analyses included two phases. First, a descriptive analysis was used to systematically compile and convey the results of the interviews, and second, a remote sensing technique was applied for obtaining information about the objects without direct contact (Lillesand *et al.* 2004). Remote sensing was used to analyze the spatial pattern of the abrasion process, which was also supported by field observations. The remote sensing technique involved the interpretation and digitization of GeoEye and Google Earth satellite images, collected from 2009 to 2018. After conducting a geometric correction process, we calculated the surface of the reduced area. The analysis was done in ArcGIS 10.3 ESRI license and the Universal Map Downloader. We used the Garmin 68S GPS during fieldwork.

Results and Discussion

Description of Moluccan Scrubfowl *(Eulipoa wallacei)*

The morphology of Moluccan Scrubfowl as discovered by Wallace in 1858 is as follows: the front of the head and neck are a grayish, greenish brown, while the back is light brown. The nape of the neck and upper back are slightly grayish and blackish green. The middle of the back, wings, and external mesh of some tertiary castaneous are dark in color and most of the edges of the fur are bluish gray. The body top tail feathers, chest, and abdomen are grayish, whereas the small, tertiary feathers and tail are a pale brownish green. The middle of the abdomen is white. The primary bristles are blackish brown patches or bordered with grayish white on the outside. They have a yellow beak and black legs. The body length is 330 mm and the wing length is 190 mm (Gray & Wallace 1860, Gray & Wetmore 2011). The iris is light brown, the beak is opaque yellow, the front legs are yellow-black, and the back legs are yellowish (Ripley 1960).

Moluccan Scrubfowl is distributed throughout Halmahera, Meiti, Ternate, Bacan, Buru, Boano, Seram, Ambon and Haruku (Coates *et al.* 1997), inhabiting tropical mountain forests (Heij & Rompas 1999) up to a height of 750–1,650 m. Moluccan Scrubfowl lives alone or in pairs, is shy and difficult to separate from its nesting community. People almost never found this bird in the forest, because it lived in mountain forests with an altitude of 200–300 meters above sea level in a lime formation (Toxopeus 1922). These birds also cannot be tamed or locked in cages (Valentijn 1726). Villagers are able to detect the presence of Moluccan Scrubfowl by its call (Heij & Rompas 1999). This species has a monogamous mating system. The pair formation on Haruku Island takes place throughout the year with a peak during the dry season, i.e. October–April (Dekker & Brom 1990, Dekker 1991). At nights, these birds leave the forest, fly to the beach to make holes and lay eggs. Then, they

Figure 2. Moluccan Scrubfowl. Photo taken in Kailolo, by C. J. Heij (Heij 2001)
2. ábra Maluku-szigeteki ásótyúk. Fotó: C. J. Heij készítette Kaiolo-n (2001)

Figure 3. Moluccan Scrubfowl dig holes to lay eggs (Photo by: H. G. Saiya, 2019)
3. ábra A maluku-szigeteki ásótyúk fészekcsészét kapar a tojásainak (Fotó: H. G. Saiya, 2019)

cover the holes with sand, also partially hiding their footprints to confuse predators (Baker & Dekker 2000, Wallace 2016) *(Figure 3)*.

Moluccan Scrubfowl females also dig multiple dummy holes to protect their eggs from predators and they do not build sand dunes like other megapode types (Dekker & Dekker 1990, Dekker 1991) *(Figure 3)*. After egg-laying, the birds fly back to the forest at sunrise (Hoyo *et al.* 1994). The parents do not incubate the eggs that are kept warm by the heat obtained from the surrounding sand.

Based on the presence of Moluccan Scrubfowl and its habitat conditions, this megapode is an umbrella species. Thus, a species-based conservation approach can be used. This option was chosen because of its wide home range and many tree habitats, from mountain forest vegetation types to stable coastal vegetation. So, efforts to conserve the Moluccan Scrubfowl habitat will also preserve forests and coastal habitats.

Customary rules by the indigenous people

The indigenous people of Maluku are the type who have the potential to be effective in preserving the environment and can implement a system of social harmony based on local wisdom and environmental control. Since long ago, the people of Maluku who live on the islands have grown their local wisdom in accordance with their natural conditions and needs. The local wisdom is generally referred to as *sasi*. *Sasi* means customary rules governing the management and use of natural resources at the sea and on the land, the rules of which are made based on customary agreements and only applied to certain customary areas within the village (Xiuping *et al.* 2010, Saiya & Heij 2017) The rules of *sasi* differ among villages. *Sasi* is a cultural institution that regulates the use and management of living natural resources and the environment, i.e. *sasi* can also be understood as management for the sake of achieving quality products, quality natural resources, and economic values. *Sasi* also means teaching values related to a strong work ethic in society. This means that besides using effective and efficient production methods, people also pay attention to and pursue the highest quality of human work (Pietersz 2010, Rugebregt 2013).

Interviews with several traditional leaders taught us that *sasi* has existed in Maluku since immemorial time and is a form of joint commitment by indigenous people, traditional leaders, and government members in the village. *Sasi* also contains restrictions and sanctions in the form of fines that must be paid in case of violations. Fines can be in the form of goods, money or community work in the village. This is based on the realization that without their environment they cannot live properly, so until now, *sasi* has been maintained from generation to generation. In general, *sasi* is divided into land *sasi* and sea *sasi*. Land *sasi* covers forest products such as wood, rattan, cloves, nutmeg, and tubers. Sea *sasi* covers marine products such as fish, sea cucumbers, sea snails, and pearls. Then, after religion entered the Maluku Islands, the indigenous people switched from animistic beliefs, so the rules in *sasi* began to be harmonized with their religious ways. The fines obtained from the implementation of the *sasi* rules would also be used to meet the needs of church or mosque.

Sasi is closely related to the *kewang*. *Kewang (Figure 4)* is a position that is within the customary *adat* government that functions to regulate and oversee the implementation of the rules of *sasi*. So, the *kewang* also monitor and protect natural resources on the land and at the sea. *Kewang* and other types of position in the customary government are inherited based on descent, so not everyone in the community can easily hold certain positions in the customary order. The *kewang* usually consists of one head and several members. Moreover, they have to make regulations related to the use and control of natural resources. Sasi is a general term for the rules made by the *kewang*. Some simple examples of *sasi* rules are as follows:

1. It is forbidden to take any kind of fruit that is still unripe.
2. People are prohibited from cutting down trees that bear fruit before obtaining permission in the customary *adat* manner.
3. It is prohibited to cut off the roof/fronds of young sago before obtaining permission from the owner and also permission from the *kewang*.
4. It is prohibited to catch small-sized fish that are not suitable to be caught.
5. People must not take sea cucumbers in areas of water that have been restricted by the village government; sea cucumbers in those areas must be allowed to develop.
6. It is forbidden to take a sea snail that is still small in size and not suitable for consumption.

Related to the *sasi* for Moluccan Scrubfowl, information from several members of the *kewang* and the people in Haruku told us that Moluccan Scrubfowl has not been present in Haruku Village decades ago. However, after the emergence of the sandbank around the river estuary in Haruku Village, many Moluccan Scrubfowls colonized the area. So, the members of the *kewang* in Haruku began to clean the sandy area, which was quite wide, of the various creepers, shrubs, and grasses that grew there. At that time, Moluccan Scrubfowl had not been incorporated into the customary *adat* rules, so the people of Haruku took the eggs and birds

Figure 4. The *Kewang* (Source: Documentation from *Kewang* Haruku)
4. ábra A *Kewang* (Forrás: A *Kewang* Haruku dokumentációja)

freely. Some of them even deliberately went to the forest trapping Moluccan Scrubfowl. Then, they recognized that the Moluccan Scrubfowl are vulnerableand the *kewang* set a rule for the protection of these birds. The rule states that Moluccan Scrubfowl eggs and specimens should not be taken for consumption and sale. The rule applies until now and even predatory animals that prey on Moluccan Scrubfowl are also kept away from the egg-laying areas. Gradually, Moluccan Scrubfowl has become one of the characteristic *sasi* of Haruku Village.

Positive idealism for saving the habitat

In 2009, the Moluccan Scrubfowl egg-laying habitat took the form of a beach with vast stretches of sand extending south to the edge of a forest cliff that borders the sea and river estuary *(Figure 5)*. The egg-laying site extends to north where is the *kewang* house and it is bordered by a pig farm owned by several families living nearby. The beach vegetation at that time was dominated by *Pandanus* sp., tropical almond (scientific name = *Terminalia catappa*; Ambonese = *ketapang*), coast cottonwood *(Hibiscus tiliaceus)*, *Calophyllum inophyllum* (Ambonese = *bitanggor*, Javanese = *nyamplung*), nipa palm *(Nypah fruticans)*, sago *(Metroxylon sagoo)* and coconut *(Cocos nucifera)*, with a sandbar area of 6,675 m^2, according to the results of calculations using the remote sensing technique.

The observations and interview results showed that the condition of the egg-laying habitat was very stable in 2009 and before. In fact, many village activities were carried out in the area in order to maintain the sustainability of the area. Some people from Ambon Island also came to the area for recreation. Of course, they had to get permission from the *kewang* before they could enter the area. The *kewang* also required them not to litter in the area, and if this rule was violated, they would be subject to the customary sanctions according to the rules written in *sasi*. In addition, the *kewang* severely limited the number of visitors from Ambon to prevent damage of the ecosystem. However, research trips and environmental

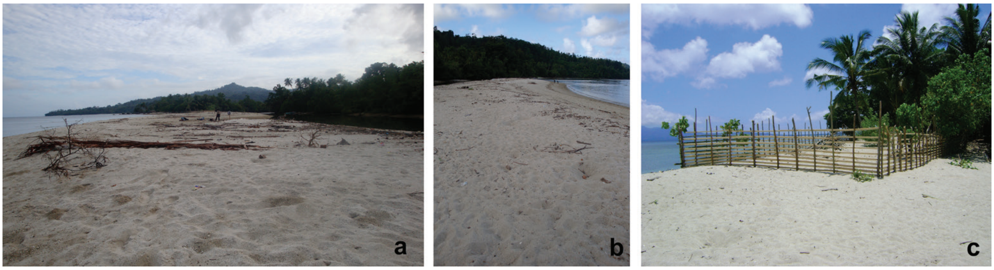


Figure 5. The condition of the sandbar in 2009 (Photo by: H. G. Saiya, 2009); a – sandbar seen from the south, b – in the middle of the sandbar, c – the northern part of the sandbar

5. ábra A homoknyúlvány állapota 2009-ben (Fotó: H. G. Saiya, 2009); a – déli, b. – középső, c – északi rész

learning are not limited by the *kewang*.

This location is often visited by local and international researchers who come to conduct various studies. The research targets in this location are diverse, including mangrove research; sago research; river and estuary ecosystem research; research on *lompa* fish *(Trissina baelama)*; sea turtle research; crab research; coral reef research; research on various mollusc species spread across the mangroves, river, ocean, and surrounding ecosystems; research on local wisdom; bird watching; and specific research related to Moluccan Scrubfowl. Many researchers have come to this location to search for Moluccan Scrubfowl. They make special observations of the birds' egg-laying behavior at night on the coast. In addition, children in Haruku Village often come to this location learning from various books donated by researchers. This location is a natural laboratory for all people.

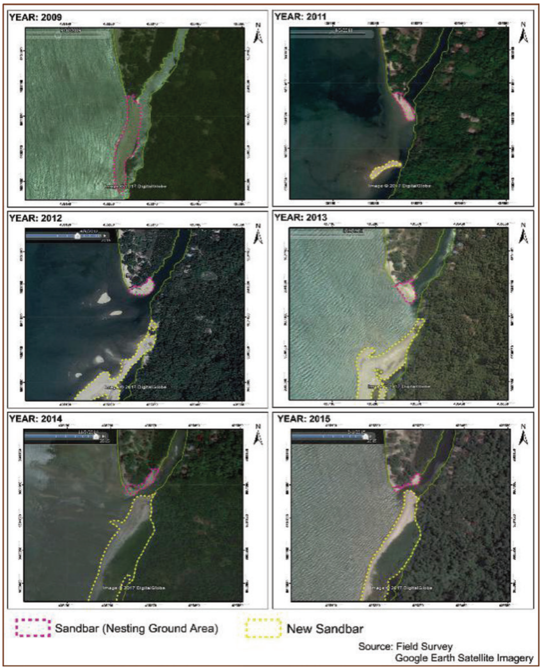
Figure 6. Before and after photos: a – before abrasion in 2010 (Photo by: H. G. Saiya); b – after abrasion in 2010 and 2011 (Photo by: H. G. Saiya & W. Nitalessy)

6. ábra Előtte-utána fotók: a – Abrázió előtti állapot 2010-ben (Fotó: H. G. Saiya), b – Abrázió utáni állapot 2010-ben és 2011-ben (Fotó: H. G. Saiya & W. Nitalessy)

However, at the end of 2010 to mid-2011, massive abrasion occurred eliminating most part of the sandbank area *(Figure 6)*.

After this event, the remaining sandbar area amounted to 1,504 m^2 in 2012, then up to 2014, the sandbar area further decreased to 1,170 m^2. According to the last calculations from 2018, the remaining area of the sandbar was 1,161 m^2. Satellite images of GeoEye and Google Earth confirmed these results *(Figure 7)*. The direction of the estuary flow has also been changed as a result of this condition.

These conditions prompted the indigenous people of Haruku Village to take various actions. Under the coordination of the *kewang*, they began to reconstruct the sandbar area in 2011. However, while abrasion was taking place, they built temporary barricades made of sacks filled with sand and stone, then arranged them along the remaining coastline area. They sought help from the local government to make embankments along the remaining beach area. Unfortunately this action resulted in a temporary solution. After 2016, abrasion increased again destroying the already poor quality beach embankments. Most of the sand substrate was swept away by the waves *(Figure 8)*.



Source: Field Survey
Google Earth Satellite Imagery

Figure 7. Time series record from satellite (Source: Google Earth)
7. ábra Műholdfelvételek (Forrás: Google Earth)

The *kewang* house was also damaged by the abrasion *(Figure 9)*. With the assistance

Figure 8. Abrasion in 2016 (Photo by: H. G. Saiya)
8. ábra Abrázió 2016-ban (Fotó: H. G. Saiya)

Figure 9. a – *Kewang* house was broken, b – the occurrence of abrasion, c – local people transport sand from other locations to be relocated in the beach (Photo by: H. G. Saiya)

9. ábra a – A megrongálódott *Kewang* ház; b – abrázió; c – a helyiek máshonnan szállítanak homokot az újratelepítéshez (Fotó: H. G. Saiya)

of BirdLife Indonesia and the Marinus Plantema, sand was brought to the location to reconstruct the area. For this activity, all aid workers in the village were mobilized to transport sand taken from other parts of the village bordering the forest to the coast *(Figure 9)*. The reconstruction activities included the replantation of the coastal vegetation. The local people received assistance from the Ministry of Maritime Affairs and Fisheries related to the recreation program for coral reefs that can help to break up the waves to prevent the are from abrasion.

Although most of the egg-laying habitat was lost, Moluccan Scrubfowl has not disappeared from the area. In fact, after the massive abrasion events in 2010 and 2011, no Moluccan Scrubfowl laid egg here. However, other activities, including *the action of kewang* routinely moving the eggs of the Moluccan Scrubfowl found along the eroded sandbank to a safer area and monitoring the hatching, successfully increased the number of breeding birds in the area. In addition, special captive breeding of Moluccan Scrubfowl was also organized and the birds were released into nature. This was initiated jointly with the local university as well as several researchers who regularly came to monitor this location.

Monitoring reconstructed locations

The sustainability of a location that has undergone reconstruction needs to be monitored. The aim is to validate whether the habitat has stabilized or not and if it is still experiencing disturbances. The results of the 2019–2020 monitoring on the reconstruction of the Moluccan Scrubfowl egg-laying habitat highlighted the following *(Figure 10)*:

1. The quality of the embankment is poor and they can be quickly damaged by sea waves. The community aims to improve the damaged embankment.
2. An ongoing replantation of coral reefs is being carried out, located around the eroded area.
3. The collection of Moluccan Scrubfowl eggs in the area along the eroded sandbank continues by the *kewang*. All of the eggs are buried again in captivity. However, the new location is still close to the egg-laying habitat. Moreover, the location may still be threatened by abrasion.
4. The release of chicks continues, leaving only two birds in captivity. The aim is to show

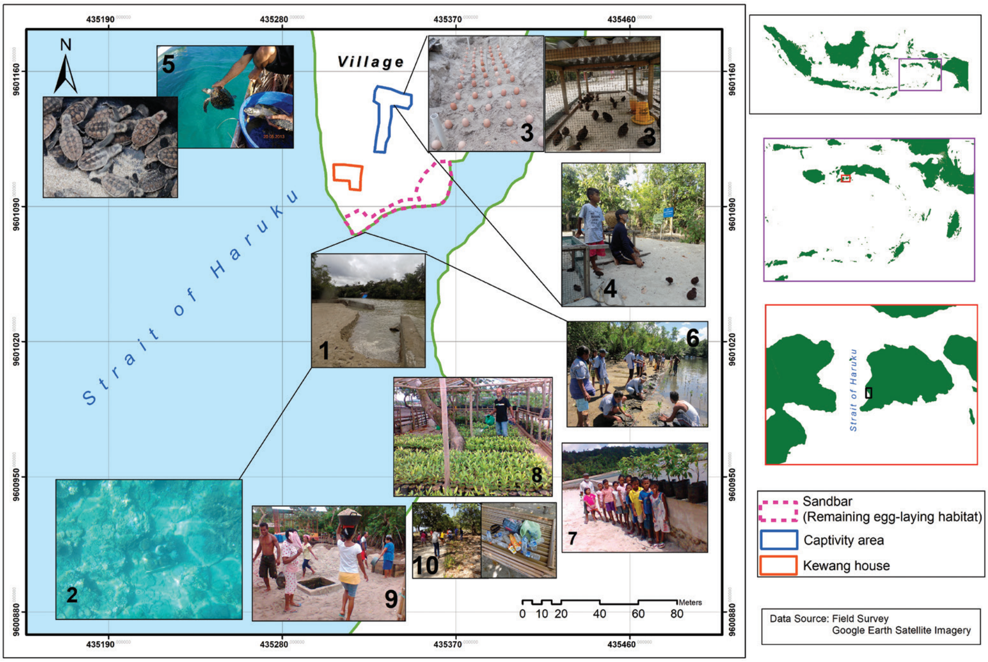


Figure 10. The results of monitoring in 2019 and 2020 (Drawings by: H. G. Saiya)
10. ábra A 2019-es és 2020-as felmérések eredményei (ábrák: H. G. Saiya)

the existence of the Moluccan Scrubfowl. When researchers, academics, and outsiders want to come and see the birds, they can immediately see them in captivity without going to the forest or staying overnight to wait for the birds to come and lay eggs. These two birds will be released in turn, once there are substitutes, which will be chosen from among the newly hatched chicks.

5. Aside from being only egg-laying habitat for Moluccan Scrubfowl, the sandbars that are lost due to abrasion are also spawning grounds for sea turtles. So, at the time of the abrasion disaster, the *kewang* found many turtle eggs swept away by the waves. After the habitat underwent gradual reconstruction, turtle eggs that continue to be found in the area are collected by the *kewang* and transported to a safer location next to the Moluccan Scrubfowl captive breeding area. Turtles also hatch in the area, and usually the *kewang* will release them, involving children of elementary and secondary schools, along with other people who are interested in the releasing of the turtles.
6. There are *kewang* nurseries for mangroves around the Moluccan Scrubfowl captive breeding area, and the community voluntarily planted mangroves along estuary areas bordering the Moluccan Scrubfowl nesting habitat. Considering that mangroves are a good antidote to abrasion, these activities are carried out, as well as, caring for and protecting mangrove seeds that have been planted.
7. The *kewang* initiated early education about being environmentally conscious for elementary and junior high school children in Haruku Village, so that they can be involved in every activity. In addition, the *kewang* also formed the Little Kewang, which trains

children to protect and preserve the natural environment. These children report activities they consider as acts of environmental destruction or violations of the customary rules related to the natural environment.

8. The *kewang* created a seedling house for various types of mangroves, cloves *(Syzygium aromaticum)* and nutmegs *(Myristica fragrans)*.
9. The local people continue to independently procure sand *(Figure 9)*.
10. The *kewang* conducts routine garbage collection programs along the coast of Haruku village to prevent threats to the health and stability of the coastal habitats.

Based on various conservation efforts undertaken by indigenous people in Haruku Village, they have used their local wisdom to maintain the Moluccan Scrubfowl nesting habitat. An abrasion disaster that removed most of the coastal habitat made people more intensely concerned about the area. The engagement, compliance, and voluntary desire of indigenous people to save coastal habitats in a form of social security action used in the environmental field. The people began the action with a species-based conservation approach but continued with an area-based conservation approach and local wisdom/customary law, so that the people not only directly saved the Moluccan Scrubfowl species, but also saved the entire existing coastal habitat. The local wisdom of indigenous people is a form of global wealth

Figure 11. *Kewang* of Haruku on a conference of Aliansi Masyarakat Adat Nusantara (AMAN) (The leader of *Kewang* Haruku, second from the right side). Source: Documentation from *Kewang* Haruku

11. ábra *Kewang* Haruku egy AMAN által szervezett konferencián (A vezető jobbról a második.) Forrás: A *Kewang* Haruku dokumentációja that makes an important contribution to achieving sustainable development, for the culture related to environmental conservation that has developed in indigenous people should not be eliminated (Lertzman & Vredenburg 2005). However, the tendency to work directly with indigenous people/local communities has gradually disappeared as nongovernmental organizations (NGOs) have come to be prioritized and considered as the main drivers of conservation. Conservation priorities change and lead to conservation strategies with a larger scale and more developed science, but we should remember the social reality of indigenous people in determining their own conservation agenda (Chapin 2004). So, what exactly is the position of the indigenous people?

The position of indigenous people is actually as conservationists, and their position must not be changed. Third parties who come to help can only act as companions. In this case, scientific organizations such as BirdLife Indonesia and the Marinus Plantema foundation, as well as several academics, were assistants who together sought solutions against habitat destruction, but the ones who determined and implemented the solutions were the indigenous people of Haruku Village. States and academics should not treat indigenous people *(Figure 11)* as clients, but they should be involved at all levels of decision making (Mauro & Hardison 2000), whether it is related to the natural environment, spatial uses, or various other matters. Moreover, indigenous people make up communities that are truly associated with their territories for a very long period. This is what makes them to truly understand what is happening in their area (Colchester 1994, 2013). Thus, even to carry out conservation efforts, indigenous people must be socially and culturally prepared. All they need are assistance and monitoring.

Conclusion

Conservation is clearly a continuous effort that must be made to maintain the sustainability of natural resources. Habitats that are threatened with damage can be revived through intense habitat reconstruction efforts. In the case of egg-laying habitats for Moluccan Scrubfowl affected by abrasion, the main conservation actors are the indigenous people. They have lived together with their environment and depend entirely on the natural products around them to meet their daily dietary needs, so even the smallest environmental changes will have a direct impact on them.

The abrasion process that destroyed the Moluccan Scrubfowl egg-laying habitat left a remaining sandbar with an area of 1,161 m^2, which is approximately 17% of the area of the initial sandbank of 2009 (6,675m^2). This not only affected the Moluccan Scrubfowl but also damaged the surrounding support areas by destroying the coastal vegetation; disrupting turtle nesting and even causing the deaths of a part of the population; and causing instability in the estuary conditions and other physical damage. The efforts of the indigenous people in the reconstruction of this area are a step in the right direction.

Despite many obstacles faced over the years, the local wisdom of the indigenous people proves that species conservation based on habitat conservation can be carried out. Even though habitat restoration is a long process, the concrete steps taken by the indigenous people indicate that humans are truly responsible for their environment.

Furthermore, the position of indigenous people as conservationists is need to be maintained. Indigenous people must be given the opportunity to decide what should be done to overcome all forms of disturbance in their habitat. NGOs, researchers, and academics should only monitor the processes and provide input. Indigenous people should not be used as a tool for fulfilling the work programs of NGOs or governments. In addition, they should not be used as objects, but rather as partners. They are an important part of the power of environmental conservation.

Finally, it can be seen that the Moluccan Scrubfowls lay their eggs at these locations because indigenous people invested a huge amount of effort into the reconstruction of the egg-laying habitats of these birds. Indigenous people also built breeding sites to protect the eggs buried by female birds. During these actions, the indigenous people were assisted by various researchers from local universities, so the breeding sites became a research location. Specifically, for the Moluccan Scrubfowl egg-laying habitat, the activities carried out by indigenous people were as follows: making embankments, adding sand to the eroded area, replanting supporting coastal vegetation, and constructing breeding sites.

The community also made efforts to restore the surrounding support areas that were also damaged. The activities carried out were as follows: replantation of coral reefs, establishing turtle breeding sites, creating mangrove nurseries, planting mangroves, setting up nurseries for other plant species such as cloves and nutmegs, picking up trash along the coast, and providing early education for children in how to be environmentally conscious.

The results of this study indicated that conservation is an ongoing collaborative effort involving indigenous people or local communities, i.e. the people who live in the area. Effective conservation is continuously places habitat restoration as its initial objective, so that the intended species will be saved.

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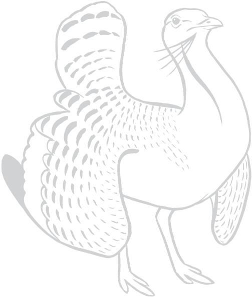

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A cross-sectional study on knowledge, attitude and practices related to owls in central Punjab, Pakistan

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Abstract Owls are considered as dominant predators for control of rats and mice population in agricultural fields and presently their populations are continuously declining in Punjab, Pakistan. The present study was aimed to assess the knowledge and attitude of people of rural and urban areas about the declining trend of owls. During this survey, more than 1600 people were asked to collect information regarding the owl populations from six localities including Faisalabad, Sialkot, Jhang, Lahore and Bahawalnagar. Four parameters were the major part of the questionnaire: familiarity, misconceptions, awareness about owls and their acceptance as a biological controlling agent. The results revealed that about 95% of people were familiar with owls in the agro-ecosystem. Only 15.6% of people thought that owls should be eliminated; 23.0% were of the opinion that owl's presence in a locality leads to ruination; 33.3% agreed that the owls presence was a sign of bad omen; 41.8% considered them as signs of foolishness; 47.0% believed that owl's body parts were used for black magic purposes. In contrast, 50% of people acknowledged that owls are beneficial to humans; 60.3% knew that owls are the enemies of rodents, 67.7% agreed that they are suppressors of rats and mice and 63.8% agreed that artificial nest boxes can serve as their nests and roosts. It was encouraging to know that 74.8% showed their willingness to enhance the owl's population on their farms, and 74.0% were willing to permit the installation of nest boxes in or near the villages. The study of attitudes of respondents towards owl will help to develop an effective conservation strategy and to boost owl's population in croplands for biological control of rats and mice.

Keywords: awareness, biological control, familiarity, misconceptions, owls, survey

Összefoglalás A baglyokat a mezőgazdasági területek domináns ragadozóiként tartják számon, mint a patkányok és egerek populációjának szabályozói. Állományuk folyamatosan csökken a pakisztáni Pandzsábban. Jelen tanulmány célja a vidéki és városi térségekben élők tudásának és hozzáállásának értékelése volt a baglyok számának csökkenésével kapcsolatosan. A felmérés során több mint 1600 embert kértek fel, hogy gyűjtsenek információkat a bagolypopulációkról hat helységből, beleértve Faisalabad, Sialkot, Jhang, Lahore és Bahawalnagar településeket. A kérdőív fő részét négy paraméter adta: az ismertség, a tévhitek, a baglyokkal kapcsolatos tudatosság, valamint a baglyok biológiai szabályozó szervezetként történő elfogadása. Az eredményekből kiderült, hogy az emberek körülbelül 95%-a ismerte a baglyok szerepét az agro-ökoszisztémában. Az emberek csupán 15,6%-a gondolta úgy, hogy a baglyokat el kell távolítani a területről; 23,0%-uk véleménye szerint a baglyok jelenléte egy településen annak tönkremeneteléhez vezet; 33,3% egyetértett abban, hogy a baglyok jelenléte rossz előjel; 41,8% az ostobaság jeleinek tartotta őket; 47,0% úgy vélte, hogy a baglyok testrészeit fekete mágia céljára használták. Ezzel szemben az emberek 50%-a elismerte, hogy a baglyok hasznosak az ember számára; 60,3% tudta, hogy azok a rágcsálók ellenségei, 67,7%-uk egyetértett abban, hogy a baglyok szabályozzák a patkányok és egerek populációit, 63,8%-uk pedig abban, hogy a mesterséges költőládák fészkelőhelyként szolgálhatnak a madarak számára. Biztató eredmény, hogy a megkérdezettek 74,8%-a hajlandóságot mutatott a baglyok számának növelésére a gazdasága területén, 74,0%-uk pedig beleegyezett a költőládák kihelyezésébe a falvakban vagy azok közelében. A válaszadók baglyokkal kapcsolatos ismereteinek és hozzáállásának vizsgálata segít a hatékony védelmi stratégia kidolgozásában, továbbá a baglyok populációjának növelésében a mezőgazdasági termelés alá vont területeken, ahol ezáltal a patkányok és egerek állományának biológiai kontrollja is megvalósulhat.

Kulcsszavak: tudatosság, biológiai kontroll, ismertség, tévhitek, baglyok, felmérés

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Introduction

Biological control involves the suppression of pest population by a natural predator (Tooker *et al.* 2020) and can be effectively used for control of invasive species as well as local pest species. The common biological control agents are used against insects and vertebrate pests (Rondoni *et al.* 2020). These should be indigenous predator species since this will reduce the risk of any ecological disasters and control the pest species in an effective manner (Weeden *et al.* 2002).

Owls are the most effective biological controlling agents against insect as well as vertebrate pests. Among owls, the Barn Owl *(Tyto alba)* is considered a key factor in reducing the incidence of Hantavirus, largely transmitted by rodents to humans and livestock. The feeding habits of Barn Owls are highly influenced by population fluctuations of the common and water voles, which appeared to be more specialists in the selection of food items. This shows a highly complex correlation among common and water voles with forest rodents that favored the permanent establishment of roosts of the Barn Owl in woodland (Bernard *et al.* 2010). In South Australia, Barn Owls intermittently predated on a variety of rodents in the plague-affected area and played a significant role in lowering the rodent populations and ultimately decreased the incidence of the disease (Janžekovič & Klenovšek 2020). A large extent of rats and mice population in oil palm plantation in Malaysia was controlled by Barn Owls. The pellet analysis of this area showed that the diet of Barn Owl composed of 75% of the House Rat, 15% of insects, and 10% of the unidentified remnants (Puan *et al.* 2011). The Barn Owl is a generalist predator and significant variations were recorded in its dietary habits ranging from small to large rodents, with a high proportion of insects among the cultivated areas in Madagascar (Rasoma & Goodman 2007). Magrini and Facure (2008) reported House Rats, shrews, House Mouse and Cotton Rats from the regurgitated pellets of the Barn Owl. This valuable predator is facing threats to its survival in Pakistan because the local population considers it as the symbol of foolishness and misfortune associated with witchcraft, magic, birth, death, and weather calamities (Lambert 2008). Santhanakrishnan *et al.* (2012) surveyed that respondents from the nomadic tribe "Kuravas" uses owl flesh, liver, eyes to cure lung and eye-related diseases.

It is estimated that 30% of the crops are globally destroyed by rodents in pre and post-harvest times (Feldhamer *et al.* 2007). While in East Africa, Tanzania, the loss of cereal crops caused by rodents is 15%; to maize at cultivation and seedling is about 40–80%, while in western Kenya, the loss of maize (20%), wheat (34–100%) and barley (34%) is reported (Makundi *et al.* 1999). In central Ethiopia, the loss caused by rodents to cereal crops is 26% (Bekele & Leirs 1997).

Pakistan is an agricultural country where the majority of the rural populations possess small landholdings. A considerable part of their agricultural produce is lost annually to vertebrate pests (Beg *et al.* 2010). Natural control agents viz., the owls have never been used to minimize the loss caused by rats and mice populations in the country. The main conviction of using these predators as a natural control agent of rats and mice population is the belief of people associated with death and demolition. This resulted in the rejection of owls (Santhanakrishnan *et al.* 2012). The objective of this research paper is to know the attitude of people, conservation problems of owls and finally to educate farmers and students about owls.

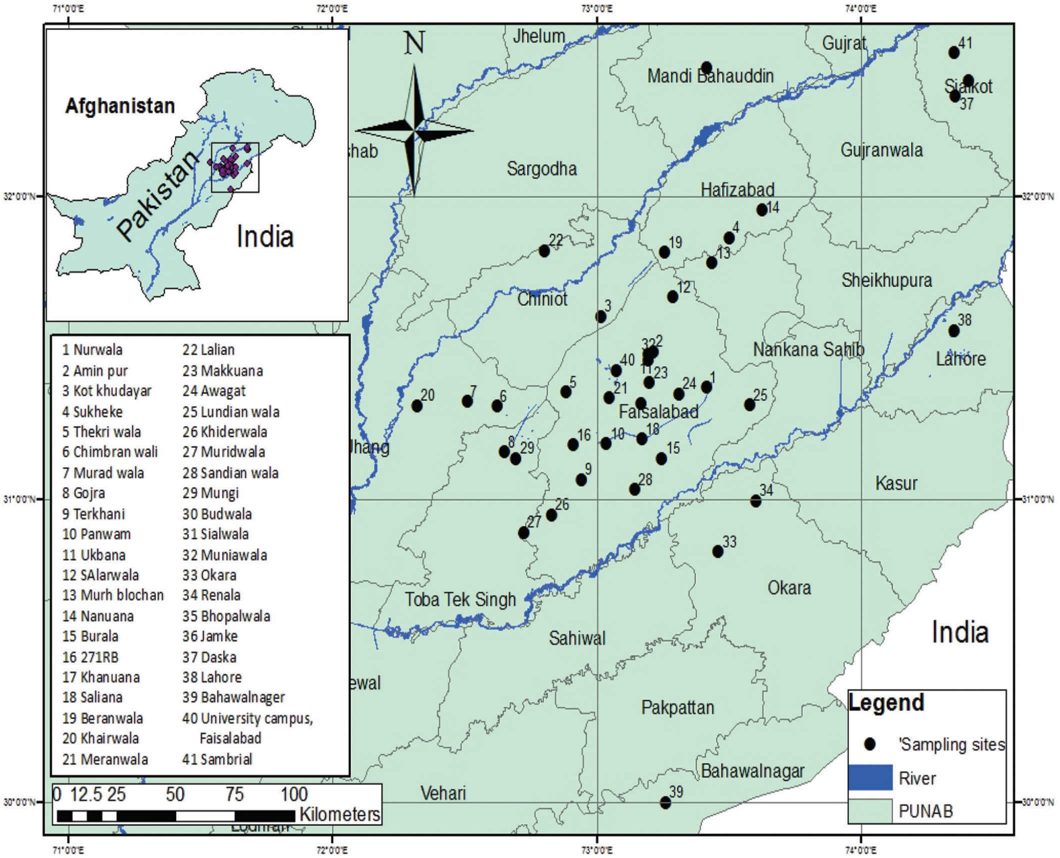

Figure 1. Map of study area showing location of sampling sites in central Punjab, Pakistan

1. ábra A vizsgálati terület térképe a mintavételi helyek elhelyezkedéséről Pandzsáb központi régiójában (Pakisztán)

Materials and Methods

Study sites and survey

The study was conducted in six localities of the Punjab (Pakistan) including Faisalabad (31°41’80’’N, 73°07’90’’E), Sialkot (32°29’50’’N, 74°32’10’’E), Jhang (30°58’33’’N, 71°65’00’’E), Lahore (31°54’97’’N, 74°34’36’’E) and Bahawalnagar (29°39’56’’N, 71°68’36’’E) *(Figure 1)*. A total of 41 sampling sites were selected for the surveys. The 90% of the sampling sites were in rural areas. Most of these areas reside along extensive canal systems in central Punjab. The province of Punjab comprises of nearly 50% of the country’s population. Study areas had three major seasons: a hot season usually during the months of April-June, when the mercury rises as high as 44 °C, a rainy season usually during the months of July-September, with an average annual rainfall of 46 cm in the plains, and a mild season during the rest of the year when the temperature decreases as low as 5 °C (Khan *et al.* 2013).

A questionnaire was developed by following Frary’s guidelines (Frary 1998). The age distribution of respondents is 19 or below; 20–35; 36 or above in years and education segregation was below matric; matric; intermediate and above. The following parameters were the part of questionnaire and asked from target human population in Punjab, Pakistan viz., familiarity with owls (owl sighting, types of owls, benefits of owls, medicinal value and enchantments), misconceptions about owls (sign of bad omen, killing of owl, sign of foolishness, causes of ruination), awareness about owls (rat population control, annual consumption of rats, biological controlling agent, knowledge about rodent control), management of owls as biological control agent (installation of nest boxes, location of nest boxes).

All these parameters were analyzed statistically using Chi-square test to calculate deviation between expected (E) and observed (O) data by using Minitab 16 statistical software. Calculated deviation was further used to know the probability (Lancaster & Seneta 2005).

Results

Familiarity with owls

Out of the total 1606 people who responded to the questionnaire, 95.0% were familiar with owls. The overall response of the respondents from the different localities varied significantly (X^2=17.15, D.F.=5, P=0.001). Out of these respondents, the highest percentage was familiar with Little Spotted Owlet *(Athene brama)*. The species-related variations in awareness significantly varied from respondents of various regions in the study area (X^2=55.37, D.F.=10, P=0.001). More than 50% of respondents of five cities viz., Faisalabad, Sialkot, Jhang, Lahore and Bahawalnagar gave a positive response regarding the beneficial role of owls. However, a small percentage showed ignorance. The response of the respondents varied significantly among different regions of the study area (X^2= 4.11, D.F.=10, P=0.001). There was no clear-cut difference in their perception regarding the beneficial role of owls among the respondents of survey. It was found that 47.4% of respondents believed that bones, blood, etc. of owls have medicinal. The response of the respondents varied significantly (X^2=160.11, D.F.=10, P=0.001). The respondents from Sialkot and Jhang were in the greater proportion who believed that owls had medicinal value. More than 50% of respondents considered that owls were used in black magic. However, a small percentage of respondents who filled the questionnaire were not in favor of this response. The locality related variations in response varied significantly (X^2=131.40, D.F.=10, P=0.001). There was little difference in the attitude of the respondents towards the owl's use in black magic between localities *(Figure 2)*.

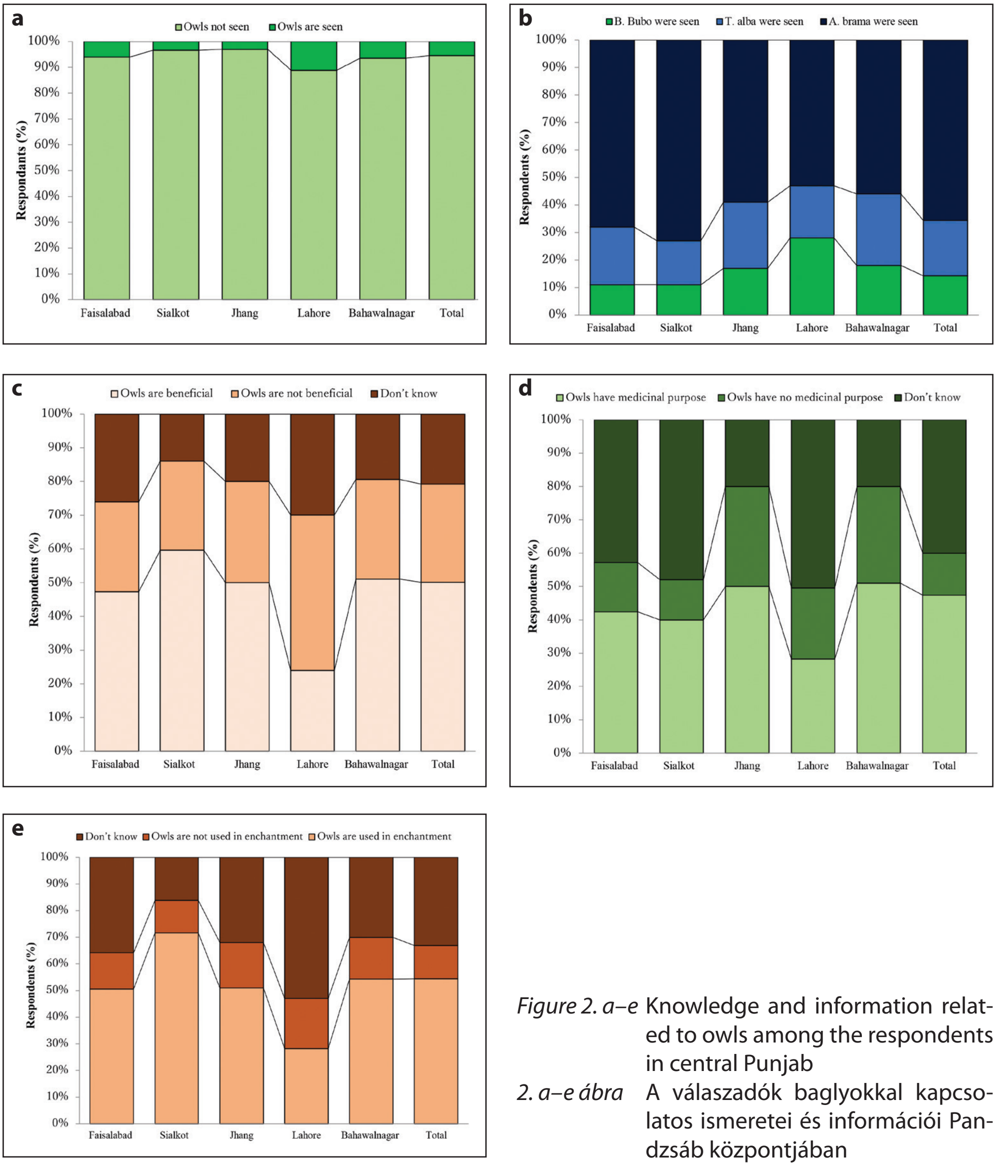

Figure 2. a–e Knowledge and information related to owls among the respondents in central Punjab

2. a–e ábra A válaszadók baglyokkal kapcsolatos ismeretei és információi Pandzsáb központjában

Misconceptions about owls

More than 45% of the people who responded did not consider as a sign of a bad omen. However, more than 35% of the respondents were agreed with the opinion that owls are sign of a bad omen and a very small number of the respondent was ignorant. A significant variation in response was observed from different localities of the study area (X^2=104.33, D.F.=10, P=0.001). The respondents from these localities indicated no clear-cut difference in the perception that the owls were not a sign of bad omen. Only 15.0% of the respondents thought that the owls should be destroyed because they are ominous and bring bad luck. The response in different localities was significantly different (X^2=45.8.3, D.F.=5, P=0.001). More than 50% of respondents gave a positive response regarding the presence of owls as a cause of ruination. However, more than 20% of people were in favor of this argument. The locality related variations in the opinion of the people varied significantly from area to area (X^2=44.14, D.F.=10, P=0.001). Owls are a sign of foolishness; this argument was supported by more than 40% of people. However, the same percentage was against this notion. The locality related variations in the people's response varied significantly from area to area (X^2=53.29, D.F.=10, P=0.001) *(Figure 3)*.

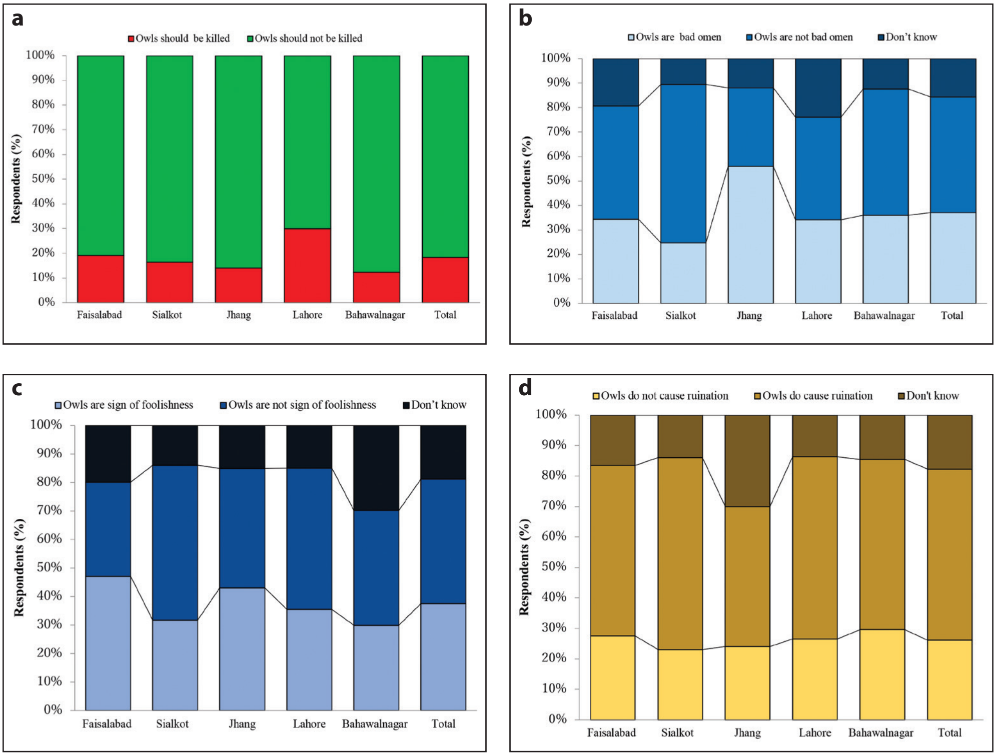

Figure 3. a–d Misconceptions related to owls among the respondents in central Punjab
3. a–d ábra A baglyokkal kapcsolatos tévhitek a válaszadók körében Pandzsáb központjában

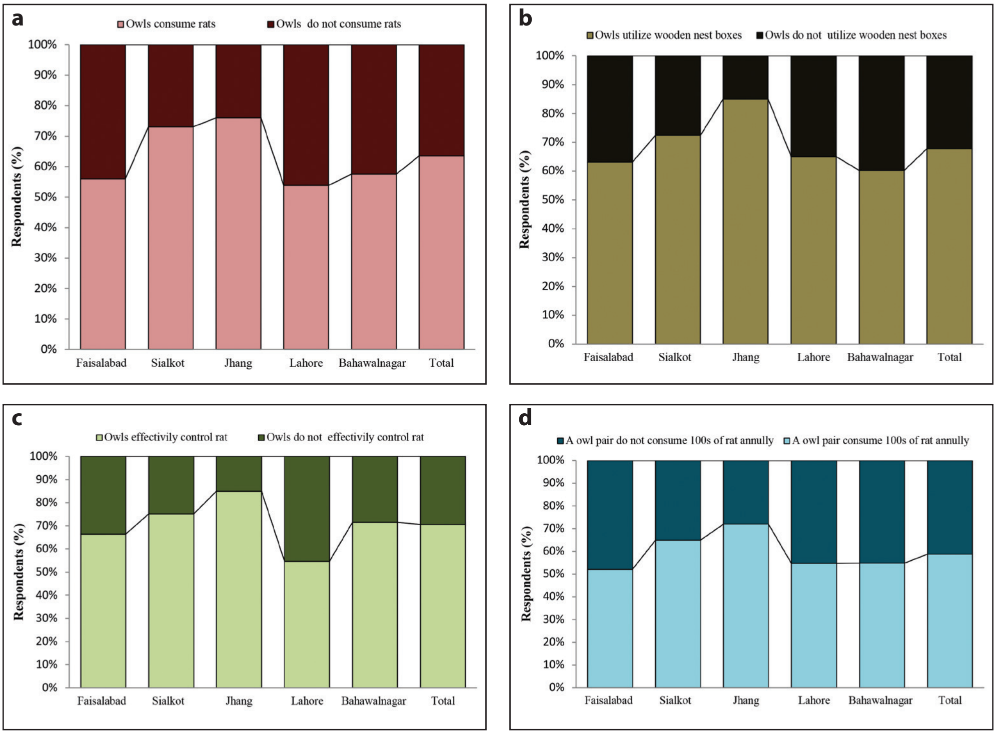

Figure 4. a–d Awareness level of respondents about role of owls in agro-ecosystem of central Punjab

4. a–d ábra A válaszadók ismerete a baglyok agro-ökoszisztémákban betöltött szerepéről Pandzsáb központjában

Awareness level of owls

A high percentage of respondents gave a positive response regarding the consumption of rats by owls while the rest responded negatively. The locality-related variations in the response of the people were highly significant (X^2= 61.69, D.F.=4, p=0.001). More than 60% of all the people who responded gave a positive response regarding the role of the owls as suppressors of rats and mice populations. The locality related response with respect to this point varied significantly (X^2=52.71, D.F.=5, P=0.001). The respondents from Jhang, Sialkot, and Bahawalnagar were better informed than those of the other localities. More than 50% of respondents gave a positive response regarding the potential of owls to control rats. The locality-related variations in the responses varied significantly (X^2=81.56, D.F.=5, P=0.001). Respondents from Jhang and Sialkot were more knowledgeable in this respect as compared to others *(Figure 4)*.

Willingness of respondents to keep owls in cropland

More than 70% of respondents was willing to install boxes in cropland and near to the villages. The variations in the response were found to be non-significant from area to area *(Figure 5)*.

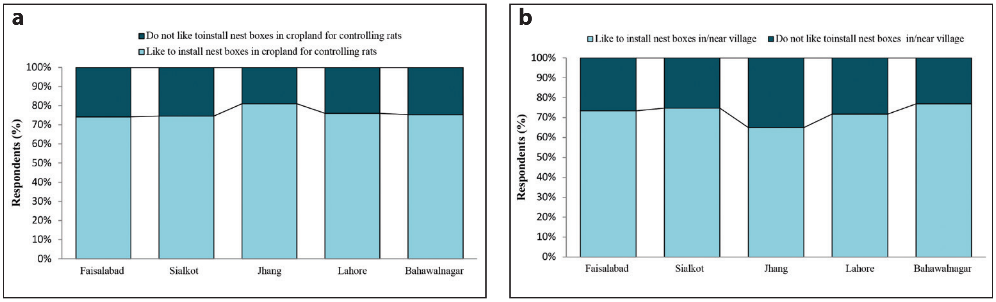

Figure 5. a–b Willingness of respondents to conserve owls in cropland of central Punjab
5. a–b ábra A válaszadók hajlandósága a baglyok megóvására Pandzsáb középső részén

Age and education-related knowledge of respondents with owls

Age-related variations among the respondents regarding the familiarity with owls were not statistically significant. The education-related variations regarding the familiarity with owls were also non-significant. Familiarity with the owls among the respondents was highest for Little Spotted Owlet. Variations in the level of awareness were non-significant for various age groups. Variations in awareness related to the education of the respondents were highly significant (X^2=17.82, D.F.=4, P=0.001). The respondents with the lowest education level were best familiar with Eurasian Eagle Owl *(Bubo bubo)* and Little Spotted Owlet, whereas those with the highest education level were best familiar with Barn Owl. Age-related variations regarding the beneficial role of owls were highly significant (X^2=12.54, D.F.=4, P=0.001). The proportion of the respondents of 35 years in age or above was somewhat greater than the younger respondents regarding their belief about the beneficial role of the owl. Responses of the respondents of different education levels varied significantly (X^2=17.67, D.F.=4, P=0.001). The respondents having the lowest educational qualification were in greater proportions than the others who believe that owls were beneficial to humans. The age-related variations varied significantly (X^2=30.06, D.F.=4, P=0.001). The proportion of the respondents of older age was greater than those of the younger people. The response regarding the medicinal importance of the owls among the people of different educational levels varied significantly (X^2=8.71, D.F.=4, P=0.001). The proportion of respondents having Intermediate or better qualifications who believed that owls had medicinal value was relatively smaller. More than 50% of the respondents considered owl's use in black magic. The age-related variations varied significantly (X^2=19.73, D.F.=4, P=0.001). The proportion of older respondents than younger ones who believed that owls were used in black magic was greater. Education had a significant impact on the attitude of the people towards the owls. The opinion of the people of different education level varied significantly (X^2=16.97, D.F.=4, P=0.001). The proportion of respondents of below matric qualification was greater than the other educational levels who believed that owls were used in black magic *(Figure 6)*.

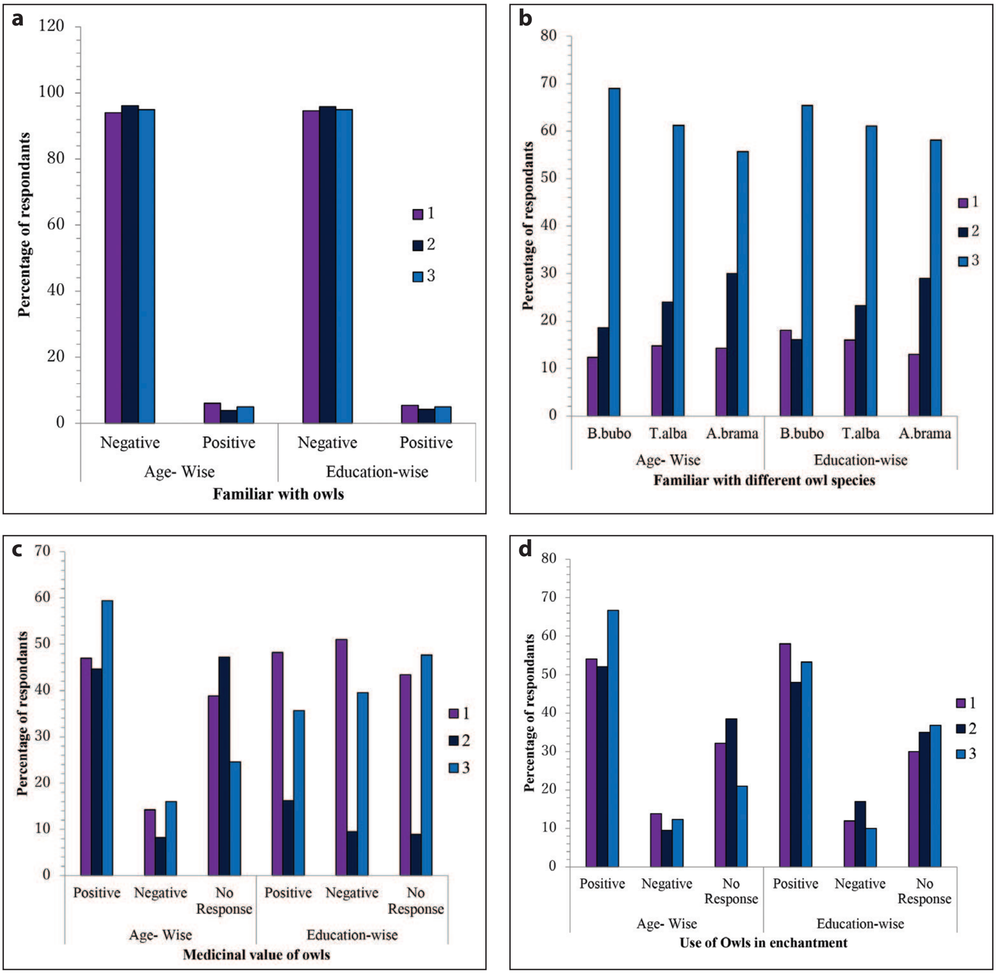

Figure 6. a–d Age and education related knowledge of respondents with owls. 1=19 or below: below metric; 2= 20–35: Matric; 3= 36 or above: intermediate or above

6. a–d ábra A baglyokkal kapcsolatban kérdezett válaszadók kor és iskolázottság szerinti százalékos megoszlása tudásuk tekintetében

Age and education-related misconceptions about owls

The proportion of the respondents of 19 years in age or less were greater than the older respondents regarding their belief that owls were a sign of bad omen. The age-related variations in the perception of the people for the owls were significantly different (X^2=14.36, D.F.=4, P=0.001). The respondents having educational qualification up to intermediate or above were in greater proportion than the others who considered the owls as not a sign of bad omen. More than 76% of respondents of various age-related categories were against killing of owls. The variations in their belief that owls should be destroyed because they brought misfortune were highly significant (X^2=10.72, D.F.=2, P=0.001). More than 80% of the people with different educational background was not agreed to destroy owls on misfortune ground. Age-related variations in the belief of the people that owls should be destroyed because they brought misfortune were highly significant (X^2=21.49, D.F. =4, P=0.001). Some of the respondents were of opinion that the presence of owls can cause ruination. However, more than 50% of people responded negatively and the rest expressed no opinion. The age-related variations in the opinion of the people concerning this point were not significant. Education had a significant impact on the attitude of the people towards the owls. The variations in the opinion of the people of different educational backgrounds varied significantly (X^2=11.77, D.F.=4, P=0.001). The age-related variations were found to be statistically non-significant. The proportion of respondents having intermediate or better educational qualifications who believed that owls were the cause of ruination was relatively smaller. More than 40% of the respondents considered owls as a sign of foolishness. The variations in the Education-related perceptions were not statistically significant *(Figure 7)*.

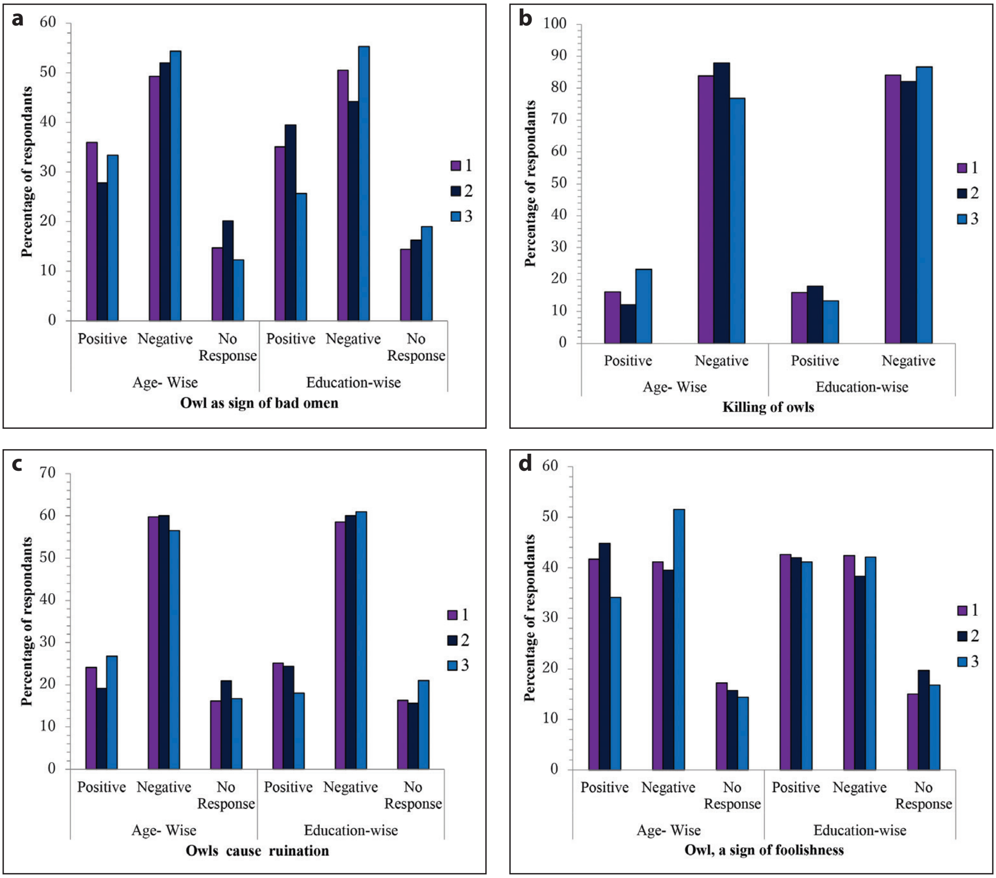

Figure 7. a–d Misconceptions about the owls among the respondents in central Punjab. 1=19 or below: below metric; 2= 20–35: Matric; 3= 36 or above: intermediate or above

7. a–d ábra A baglyokkal kapcsolatos tévhitek a válaszadók körében Pandzsáb központi részén (kor és iskolázottság szerinti megoszlás)

Age and education-related awareness level of owls

More than 60% of the respondents had the opinion that the owls consumed rats, while the rest denied this idea. The respondents of younger ages were better informed than older people. This variation was found to be highly significant (X^2=30.07, D.F.=2, P=0.001). The awareness regarding the consumption of rats by the owls among the people of different education levels varied significantly (X^2=41.4, D.F.=2, P=0.001). People with the lowest level of education exhibited better awareness than those having better education backgrounds. Age-related responses varied significantly (X^2=6.03, D.F.=2, P=0.001). The respondents of 19 years or below gave the best positive response. The response levels regarding the use of nest boxes for nesting and roosting purposes varied significantly among the people with different levels of education (X^2=38.07, D.F.=2, P=0.001). People with lower educational backgrounds gave better positive responses. The younger respondents outnumbered the older people regarding their knowledge about the suppressing role of the owls for the rodent's

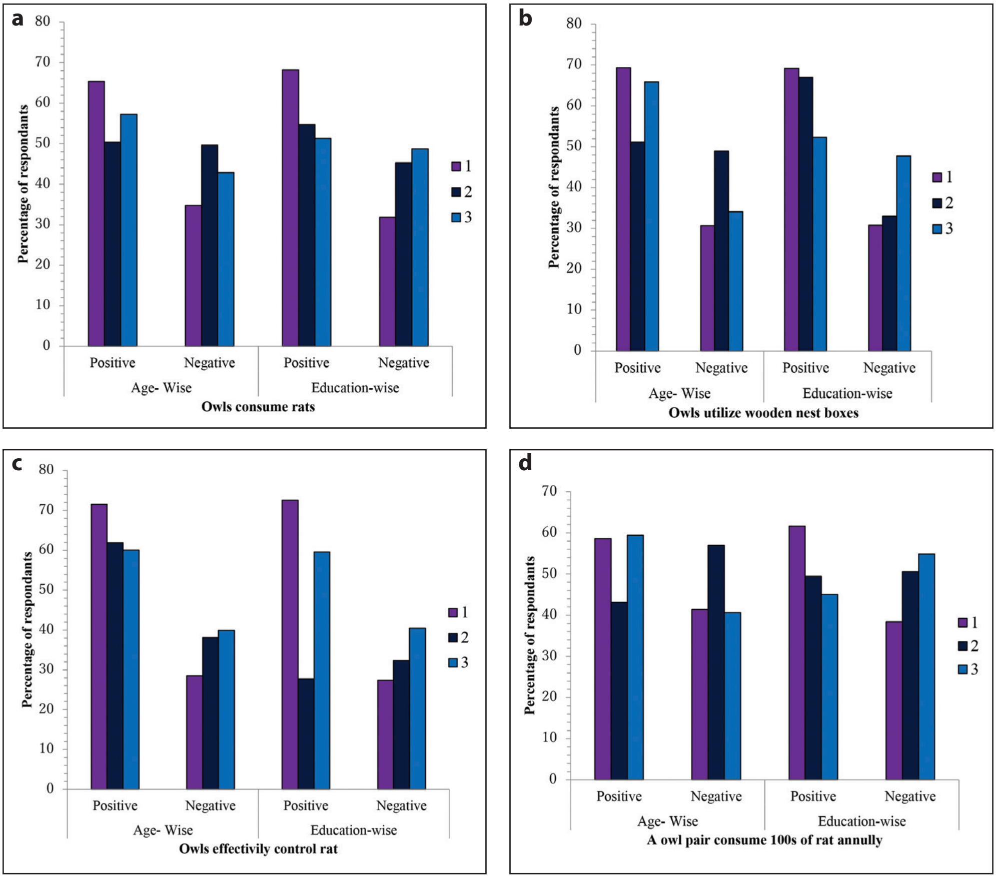

Figure 8. a–d Awareness level of respondents about the owls in central Punjab. 1=19 or below: below metric; 2= 20–35: Matric; 3= 36 or above: intermediate or above

8. a–d ábra A válaszadók baglyokkal kapcsolatos ismerete Pandzsáb középső részén population. The age-related variations were highly significant (X^2=17.55, D.F.=2, P=0.001). Respondents with the least education were better informed about the anti-rodent role of the owls *(Figure 7)*. The education-related variations were found to be highly significant (X^2=22.91, D.F.=2, P=0.001). The respondents those belonging to the younger and older age categories were better aware than the intermediate age category. The age-related variations in the awareness about the intensity of owl predation on rodents were significant (X^2=32.2.4, D.F.=2, P=0.001). The respondents having the lowest educational background were better informed about the degree of intensity of the owl predation on rats and mice. The age-related variations in this respect were significant (X^2=36.37, D.F.=2, P=0.001) *(Figure 8)*.

Age and education-based willingness of respondents to keep owls in cropland

Variations in the age-related positive responses regarding keeping the owls in the croplands among the respondents varied from 74.0% to 79.0%. These variations were found to be non-significant. Education had a significant impact on the attitude of the people towards the owls. The variations were found to be significantly different at a statistically significant level (X^2=6.39, D.F.=2, p=0.001). The level of positive response was the best among the best-educated respondents. The variations in willingness to install boxes in or near villages were not significant concerning the age of the respondents. Education level related variations were found to be non-significant among people having different educational backgrounds *(Figure 9)*.

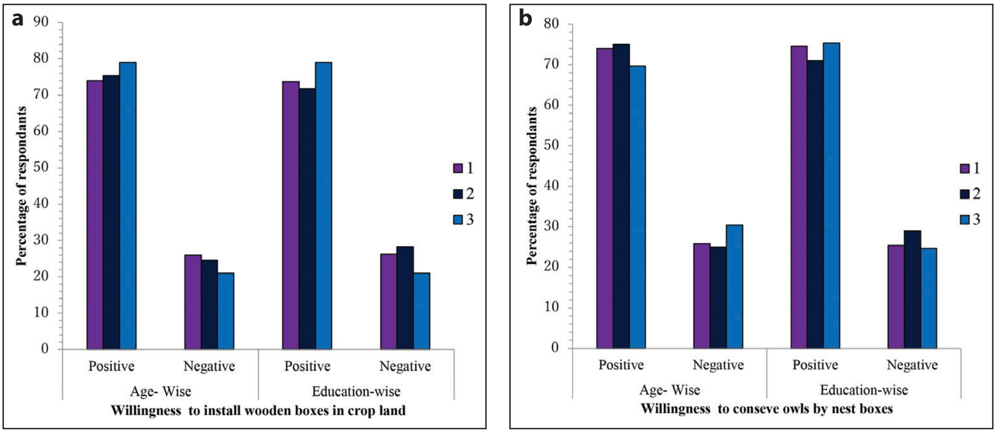

Figure 9. a–b Willingness of respondents to keep owls in cultivations of central Punjab. 1=19 or below: below metric; 2= 20-35: Matric; 3= 36 or above: intermediate or above

9. a–b ábra A válaszadók bagolytartási hajlandósága Punjab központjában

Discussion

The survey was conducted to know about the attitude of the people vis-a-vis owls presented interesting information. The questionnaire was divided into four major parameters viz., familiarity, misconceptions, awareness about owls, and their acceptance as a biological control agent. The familiarity of respondents with Eurasian Eagle Owl, Barn Owl and Little

Spotted Owlet was 12.6%, 20.1%, and 62.3%, respectively. Only 47.0% of participants responded that owls have medicinal importance, 2.6% responded in negative and 40% were unaware. About 54.4% of respondents consider owls were used in enchantment. However, 12.5% do not know about such use. About 33.3% agreed that the owls presence was a sign of a bad omen, whereas, 50.6% were not agreed. Only 15.6% of the people in the sample thought that owls should be destroyed, whereas, 84.4% responded negatively. Of the respondents, 23.0% believed that owl's presence in a locality leads to ruination, whereas 59.5% were of the view that the presence of owls is not causing ruination. About 41.8% considered them as signs of foolishness but an almost equal number of people (46.6%) did not agree. Of the respondents, 47.0% believed that owl's body parts were used for black magic purposes, whereas 33.1% were unaware about the notion but 12.5% responded negatively. The brighter side of the picture is that 50% of the people acknowledged that the owls are beneficial to mankind; 60.3% knew that the owls were predators of rodents, and 67.7% agreed that they were suppressors of rats and mice populations. 63.8% of the people agreed that nest boxes could serve as nests and roosts. It was very encouraging to know that 74.8% showed their willingness to allow the installation of nest boxes for the owls on their farms and were willing to permit the installation of the nest boxes in or near the villages.

In Madurai, Tamil Nadu, India Santhanakrishnan *et al.* (2012) reported that 54.2% of the respondents knew about two owl species Barn Owl and Little Spotted Owlet, 28.3% of the respondents told rodents are the staple food item while 30.1% thought about insects. More than 60% of respondents believed that owls are being hunted for food; 23.7% believed in medical use. Of the respondents 69% showed strong beliefs about superstitions about owls; 86% linked owls with sudden death while 72.3% responded that they have not seen such death directly but have heard of it; 19.4% mentioned it as a sign of evil and misfortune. Nearly 56% of respondents were of the view that artificial nest boxes attract owls towards agriculture fields and 65% confirmed the use of nest boxes as perching sites. Majorities of people were classified as bad omen (53.2%) while 2.5%% were considered owls as beneficial; 14.5% emphasized that owls are birds; 6.2% considered them harmful while 3.5% as fearing birds.

A total of 12142 pairs of Barn Owl were estimated in England and Wales (Blaker 1934). In a similar survey conducted after 50 years (1982–85) in the same area, the estimation was 3778 pairs of the Barn Owl. This estimated result revealed a 69% decline in the Barn Owl population (Shawyer 1987). In Britain approx. 70% decline in farmland birds is caused by changes in agricultural practices a reduction in the reproductive output is caused by loss of breeding habitats due to the result of the development of drainage and agriculture extension. Overgrazing and increased use of pesticides are the severe causes of food scarcity and reduces nesting success for ground-dwelling birds (Vickery *et al.* 2001, Newton 2004). Arthropods are highly affected by the use of herbicides, which represents staple food items in the avian diet, increasing the mortality rate of avian fauna through the food chain in North America (Sibly & Hone 2002).

Rodents are nocturnal mammals that are the strong pest of agricultural cash crops. Destructive habits of rodents possess heavy economic loss to the agriculturists. In the agro-ecosystems, rodents caused significant damage to cereal crops (Jacob & Tkadlec 2010). Loss caused by the rodents to cereal crops such as rice, wheat, and maize is between 5–10% at the pre-harvest level in India and China. Post-harvest damage of these cereal crops is higher than pre-harvest loss (Abass *et al.* 2014). The average damage caused by rodents to cereal crops in Sichuan, province of China was studied as 320 kg/hectare (Singleton & Brown 2003). The damage caused by the rodents in Philippines is 13.2% in the wet season while 8.1% in dry seasons (Stuart *et al.* 2011). In Indonesia and Malaysia, damage caused by the rodents to rice fields at the pre-harvest stage is 5% and 17% respectively (Singleton & Petch 1994). In Tanzania, damage caused by rodents to maize stored in traditional stored structure is 40.4% (Mdangi *et al.* 2013) while in Lao village damage to stored rice is 11.7% (Brown *et al.* 2013). In small crop fields, the damage caused by the 13 species of wildlife species in three communities viz*., Doumno*, *Malen*, and *Mimplala* was 100%, 94%, and 100% respectively at Dja Faunal Reserve, in Cameroon. A total of 96.7% of damage is caused by small mammals to different crops. Of the total 96.7% damage, 73% is caused by cane rats (Arlet & Molleman 2007). The average damage caused by rodents to cereal crops such as wheat (10%), rice (19%), sugar cane (7.5%), groundnuts (5.3%) (Beg *et al.* 2010). Owls are considered effective biological control agents for rats and mice populations in cultivations. (Mahmood-ul-Hassan *et al.* 2007a) found during the pellet analysis of Barn Owl that consumption of rats and mice population at central Punjab (28%), at southern Punjab (14%) and southern Balochistan (93%). Variation in the dietary composition depends upon time cultivation, harvest, and crop pattern. The regurgitated pellets of Barn Owl in lower Sindh Pakistan revealed remnants of small mammals (84%) and birds (25%) while from six districts of central Punjab (Pakistan), 75% of the diet of Barn Owl is comprised of *Suncus murinus* (Mushtaq-ul-Hassan *et al.* 1990). Insects were the main staple items of Little Spotted Owlet but the rodents stood at secondary importance (Beg *et al.* 1990).

It requires time to acknowledge owls as a biological control agent in the cultivations and different methods should be conducted to conserve Barn Owls. The installation of nest boxes within a 500 m radius in agricultural fields play a significant role in the cultivations in Beit Se’an valley, Israel. During five years, 86.7% of the nest boxes were occupied by Barn Owls. Erection of nest boxes is a very effective method for increasing Barn Owl’s population in agriculture fields (Meyrom *et al.* 2009).

Most of the superstitions are related to stories of old times, when people were more fearful and tried to get the answer about their lives and the environment. Now the attitude of people, on the whole, was in favor of the owls. Their willingness to allow the raptor to live and breed in their villages and croplands is a very encouraging thing that has emerged from the present surveys. Decidedly more people had a soft corner for the owl because of their role in inhibiting the populations of rats and mice. This sort of attitude will make things easier for workers desiring to bring owl closer to cropland for biological control of rats and mice populations.

Conclusion

Owls are considered one of the best predators of vertebrate pests in the agro-ecosystem. Human interference viz., agricultural pattern, use of pesticides, lack of knowledge, and awareness has changed its habitat, which has reduced its fecundity and declined populations in their natural habitats. Many attributes of his body structure such as starring eyes give the wise appearance, tuft of the feather on head give horned devil appearance, turning of the head and piercing cries make them mysterious birds. Over the period, these features created many misconceptions about the bird, which implicated bad impressions in the mind of people. People start believing in such old myths and superstitions, which played a negative role against owls. By providing a true picture of misconception and highlighting its beneficial aspects of owls will help in reducing pressure on the owl populations. The natural habitat of owls is disturbed and it is the need of time to develop an alternative method for conservation of owls such as the installation of nest boxes in agricultural habitats. As a biological control agent of rats and mice populations in cultivations deserve support and encouragement for the development of a conservation strategy by wildlife departments. The conservation of owl is mainly affected by anthropogenic interference. The study will provide baseline data for making conservation policy for owls by wildlife managers.

Acknowledgements

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Woodpecker foraging activity in oak-dominated hill forests in Hungary

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Abstract We documented the foraging activities of woodpeckers on selected trees in an established conservation-oriented management study in five oak-dominated forests in Hungary. We examined the tree species preference of woodpeckers as a group and the impact of specific tree characteristics on the habitat use of woodpeckers. We estimated the percentage of visible foraging signs on the trunks and upper limbs of selected trees through the winter and early spring of 2019–2020. Based on the Jacobs' index, woodpeckers preferred oak species for foraging and most foraging signs were on limbs rather than trunks. Foraging signs on trunks were more frequent on those of larger diameters and greater heights. It was also found that the lower the tree, the greater the effect of its diameter on the occurrence of signs.

Keywords: woodpecker ecology, woodpecker foraging signs, conservation, nature conservation management

Összefoglalás Kutatásunkban hazai harkályfajok táplálkozási nyomait mértük fel egy természetvédelmi erdőkezelési kutatás alapállapot felméréseként tölgy dominálta gazdasági erdőkben. Vizsgáltuk a harkályok fafaj-preferenciáját, valamint a fák egyes jellemzőinek hatását a harkályok élőhely-használatára. 2019–2020 tele és kora tavasza között mértük fel a kijelölt fákon megfigyelhető táplálkozási nyomok százalékos előfordulását a fák törzsén és a lombkoronában. Eredményeink alapján a harkályfajok leginkább a különböző tölgyfajokat preferálták, ezen belül is legnagyobb mértékben a kocsánytalan tölgyet, emellett pedig nagyobb eséllyel találtunk táplálkozási nyomokat az ágakon, mint a fák törzsén. A detektált táplálkozási nyomok a nagyobb törzsátmérőjű és magasabbak fákon voltak gyakoribbak. Minél alacsonyabb a fa, annál nagyobb hatása van a mellmagassági átmérőnek a táplálkozási nyomok előfordulására, a felsőbb magassági kategóriákban az átmérő hatása mérsékeltebb.

Kulcsszavak: harkály ökológia, harkály táplálkozási nyomok, természetvédelem, természetvédelmi erdőkezelés

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Introduction

The ecological impact of woodpecker species in wooded ecosystems is important for numerous reasons. They are considered umbrella species because through their presence they can support many other species (Melletti & Penteriani 2003, Garmendia *et al.* 2006, Puverel *et al.* 2019). They provide nesting and roosting site for various cavity-dwelling species, including invertebrates, mammals and birds such as tits (Paridae), flycatchers (*Ficedula* spp.), nuthatches (*Sitta* spp.), treecreepers (*Certhia* spp.) and some owls (Strigidae) and ducks (Anatidae)

(Gorman 2004). Certain woodpeckers can also be regarded as keystone species (Mikusiński *et al.* 2001, Virkkala 2006), for example, Black Woodpecker *(Dryocopus martius)* in Europe (Gorman 2011, Puverel *et al.* 2019) and Red-cockaded Woodpecker *(Dryobates borealis)* in North America (Jusino *et al.* 2015). The most abundant European species, the Great Spotted Woodpecker *(Dendrocopos major)*, is often categorized as a keystone species, especially in sub-optimal habitats, where there is invariably a lack of natural cavities (Pasinelli 2007). However, this species is a major nest predator of cavity-nesting songbirds and therefore, its keystone role is sometimes considered as controversial (Wesolowski 2007, Ónodi & Winkler 2016).

Woodpeckers are particularly suitable as indicator organisms (Virkkala 2006, Drever *et al.* 2008). First, most of them are year-round resident and mostly easily detectable (Lõhmus *et al.* 2010). Second, they have large home ranges (e.g. Bocca *et al.* 2007, Charman *et al.* 2010, Campion *et al.* 2020), hence they can provide information on large areas. Third, this is the only bird family in the Western Palearctic that can forage for insects within the inner layers of wood, which are threatened with extinction in intensively managed regions so that they can be monitored relatively easily (Lõhmus *et al.* 2010). They are also highly susceptible to habitat change (Mikusiński *et al.* 2001, Thompson *et al.* 2003, Mikusiński 2006). Finally, they provide identifiable foraging signs that are often specific to the group (Gorman 2015).

Many studies on the habitat and nesting requirements of woodpecker and cavity-nesting species in general have been published (Wesolowski & Tomialojc 1986, Hardersen 2004, Pasinelli 2007, Kosinski *et al.* 2017). There has been less focus on foraging habitat needs and on foraging signs. This is especially true for species-specific observations, especially in managed, commercial stands (Czeszczewik 2009, St-Amand *et al.* 2018, Aszalós *et al.* 2020). Woodpeckers that forage on bark may choose trees with different characteristics for foraging than they do for nesting, and thus, habitats appropriate for nesting may fail to include suitable foraging sites (Swallow *et al.* 1988, St-Amand *et al.* 2018). The motivation for studying artificially created snags usually relates to nesting (Brandeis *et al.* 2002, Kilgo & Vukovich 2014, Barry *et al.* 2018). Few studies examine this subject in the context of foraging needs (Aulén 1991, Farris & Zack 2005, Arnett *et al.* 2010, Aszalós *et al.* 2020).

In this study, the following questions were posed. Which tree species are preferred for foraging by woodpeckers in the studied oak forests? Does the diameter or height of trees affect how they are used? Which attributes of the studied trees influence the presence of woodpecker foraging signs? What determines, and to what extent, the number of foraging signs observed on the studied trees?

Materials and Methods

Study sites

This study was part of a detailed, conservation-oriented management project (LIFE 4 Oak Forests Project, LIFE16NAT/IT/000245), the purpose of which was to structurally enrich certain oak-dominated woodlands in Hungary through various management techniques. Within this framework, we designated ten 80×80 m (0.64 ha) square plots in 5 study sites, in which artificial standing and downed deadwood and the opening of canopy gaps will be created in the near future. The present study was a baseline research carried out prior to the planned management. Therefore, all the trees surveyed would be selected for management activities, and, in addition, control trees that would not be managed, were also selected. In the forthcoming winter of 2021–2022, there will be a follow-up survey of both the managed and control trees. Therefore, all trees selected for this study were living specimens at the time of data collection. On 10 square plots in the 5 study sites, we measured a total of 1,471 individual trees. In these study plots, we surveyed all trees with diameters of more than 10 cm at breast height (DBH). *Table 1* summarizes the data of the trees measured (species, height, diameter).

Table 1. Numbers, mean diameter, and height of the surveyed trees by species (QC – *Quercus cerris*, RP – *Robinia pseudoacacia*, C – *Crataegus* sp., CB – *Carpinus betulus*, QR – *Quercus robur*, QP – *Quercus petraea*, AC – *Acer campestre*, FE – *Fraxinus excelsior*, QPU – *Quercus pubescens*, FO – *Fraxinus ornus*, QRU – *Quercus rubra*)

1. táblázat A vizsgált faegyedek száma, átlagos átmérője és magassága fafajok szerint bemutatva (QC – *Quercus cerris*, RP – *Robinia pseudoacacia*, C – *Crataegus* sp., CB – *Carpinus betulus*, QR – *Quercus robur*, QP – *Quercus petraea*, AC – *Acer campestre*, FE – *Fraxinus excelsior*, QPU – *Quercus pubescens*, FO – *Fraxinus ornus*, QRU – *Quercus rubra*)

tree species	QP	QR	QC	QPU	QRU	CB	FE	FO	AC	RP	C
number of individuals	616	71	750	7	1	11	1	1	11	1	1
mean DBH_cm	28.1	37.09	33.24	32.2	32.5	22.87	15.3	15.6	13.7	30.6	12.6
mean height_m	20.3	23.34	23.5	18.56	25.86	17.82	19.33	12.05	13.11	19	10.67

Figure 1. Location of the study sites

1. ábra Vizsgálati területek elhelyezkedése

All study areas were within hill ranges in north-east Hungary *(Figure 1)*. The first study site is located in the Duna-Ipoly National Park, specifically in the Börzsöny Hills near the settlement of Nagyoroszi (65°08’20”N-29°62’40”E, 250 m a.s.l, 10–15° slope, 80–99 years old stands). The studied forest was dominated by sessile oak *(Quercus petraea)* – Turkey oak *(Quercus cerris)* and hornbeam *(Carpinus betulus)*. The second and third sites were situated in the Cserhát Hills, which are part of the East-Cserhát Landscape Protection Area. The second site, near the settlement of Buják (68°84’36”N-28°55’10”E, 300 m a.s.l, 10° slope, 80–99 years old stands), is a Turkey oak-pedunculate oak *(Quercus robur)* forest with a high scrub layer. The other site, in the vicinity of Garáb (69°48’84”N-29°32’60”E, 500 m a.s.l, 20–25° slope), is a 60–79-year-old deciduous woodland with sessile oak, hornbeam, beech *(Fagus sylvatica)* and Turkey oak. The final two study sites were located in the Bükk Hills (Bükk National Park) near the settlements of Cserépfalu (76°32’78”N-29°29’00”E, 250-350 a.s.l., 5–10° slope, 80–99-year-old stands) and Bükkzsérc (75°67’58”N-29°23’50”E, 350–450 m a.s.l., 10–15° slope, 40–59 and 80–99-year-old stands). Both sites are predominantly covered by Turkey oak-sessile oak forests.

Woodpecker foraging activity surveys

In the course of previous point count surveys, we detected the presence of the Great *(Dendrocopos major)*, Middle *(Leiopicus medius)*, Lesser Spotted *(Dryobates minor)*, Black *(Dryocopus martius)*, Eurasian Green *(Picus viridis)* and Grey-headed Woodpeckers *(Picus canus)* within the study sites. In most cases, it was not possible to accurately distinguish between the foraging marks that the different species made, as most are not diagnostic (Gorman 2015). From the species present in the study areas, only the black woodpecker’s foraging marks are generally identifiable to species, owing to its large bill size. Therefore, we decided not to attempt to identify signs and marks to species level, but rather the wood layers that the birds accessed. The percentage of visible foraging signs on the trunks and limbs of the surveyed trees were estimated using binoculars and naked eyes through the winter and early spring of 2019–2020. The survey differentiated four depth categories for presumed woodpecker foraging signs on trees: marks on the bark, bark scaling, excavation marks in the sapwood, excavation marks in the heartwood. ‘Marks on the bark’ means that birds had searched for prey by only superficial pecking. ‘Bark scaling’ means that birds had peeled off sections of bark and foraged beneath it. We also identified deeper excavation marks: ones that penetrated only into the sapwood and others that entered deeper into the heartwood. Heartwood was recognized by its distinctive (usually reddish) colour. We also differentiated between marks on trunks (with an estimated diameter greater than 15 cm) and on limbs (with an estimated maximum diameter of 15 cm).

Data analyses

We calculated the frequency and distribution of woodpecker foraging signs according to tree species and categories of diameter at breast height (10–20; 20.1–40 and above 40 cm) and tree height (0.5–15; 15.1–25, and above 25.1 m). Jacobs’ preference index values (Jacobs

1974) were calculated using frequency data from a previous vegetation survey in the study sites. This index represents a –1 to +1 scale from avoidance to the examined variable's preference, respectively.

We used a mixed linear model with zero-inflated beta distribution and logit link. Since beta distribution is defined on interval [0, 1], the zero-inflation part models the probability of occurrence of foraging signs. The conditional part models the area of signs when they occur. Our models included tree species, DBH, and height as fixed effects and research plots as a random factor. Main effects were tested by Type II Wald's chi-square test. Because of the limited data due to the limited availability of secondary tree species, only the pedunculate oak, sessile oak, and Turkey oak were included in the model. Analyses were done in the R statistical environment (version 4.0.2 R Development Core Team 2020) using the glmmTMB (version 1.0.2.1, Brooks *et al.* 2017), emmeans (version 1.5.4, Lenth 2021), multcomp (version 1.4-16, Hothorn *et al.* 2018) and effects (4.2-0, Fox 2003, Fox & Weisberg 2018) packages.

Results

Foraging preferences

From the 1,471 individual trees examined, 798 (54.24%) had some type of foraging marks upon them. In the study areas, woodpeckers foraged mainly upon Turkey oaks and sessile oaks *(Figure 2)*. The order of frequency of the tree species was the following: Turkey oak (51%), sessile oak (42%), pedunculate oak (5%). Other species had less than 1% of frequency: black locust *(Robinia pseudoacacia)*, hawthorn (*Crataegus* sp.), hornbeam, common ash *(Fraxinus excelsior)*, manna ash *(Fraxinus ornus),* red oak *(Quercus rubra),* downy oak *(Quercus pubescens)* and field maple *(Acer campestre)*. The most preferred tree species in terms of both trunk and limb use was the pedunculate oak. When just trunk usage was examined, the most preferred species was the red oak, and when only limbs were considered, mainly downy oak was used. However, it must be mentioned that both red and downy oaks were hardly present in the study areas, thus, these data are biased to 1–2 individual trees *(Figure 3)*. The Turkey oak can also be mentioned for trunk use and sessile oak and hawthorn for limb use as tree species utilized at a moderate level. As reflected in the negative Jacobs' index values, woodpeckers avoided common ash, manna ash, hornbeam, and field maple.

The percentage of coverage of foraging signs was the highest on trees falling in the middle DBH category. At the same time, on trees with a DBH under 20 cm, woodpecker foraging marks were scarcely present *(Figure 4)*, as is also reflected in the preference index *(Figure 5)*.

In the case of tree height *(Figure 6)*, the 15.01–25 m category was the most frequent, followed by the category of >25 m. The least utilized trees belonged to the lowest height category (below 15 m). Regarding both trunks and limbs, woodpeckers preferred the highest trees and avoided the medium-height category *(Figure 7)*.

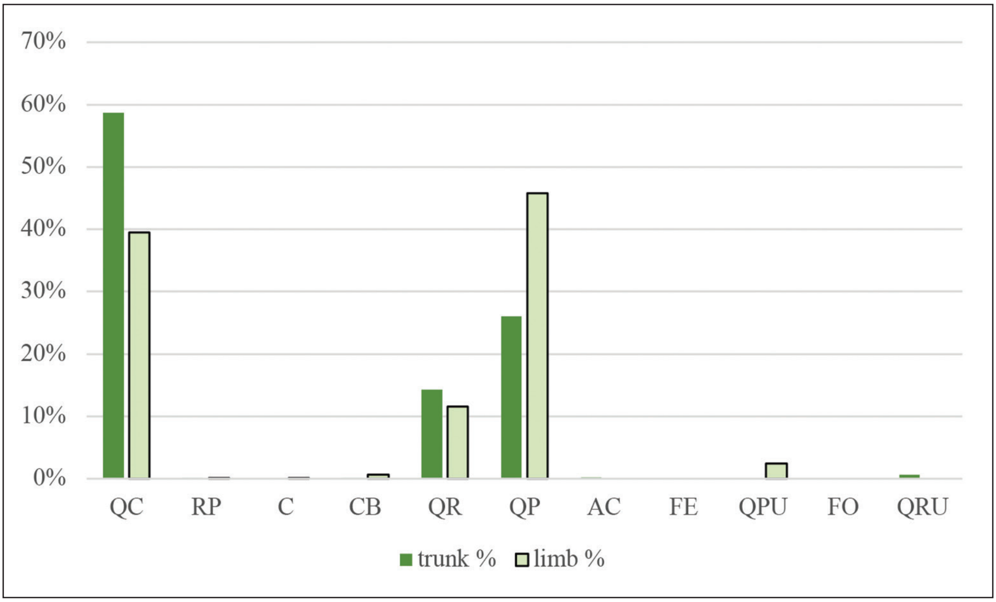

Figure 2. Percentage distribution of woodpecker foraging signs on the trunks and limbs on each tree species. (For abbreviations of tree species see the legend of *Table 1*)

2. ábra A felmért harkály táplálkozási nyomok százalékos megoszlása a törzseken és az ágakon fafajok szerint. (A fafajok rövidítését lásd az *1. táblázat* jelmagyarázatánál)

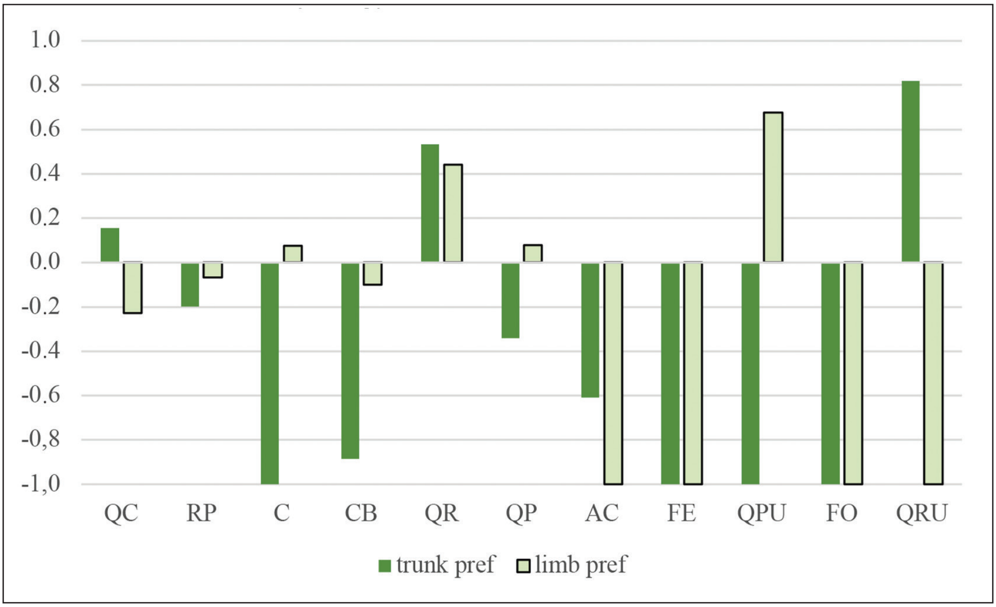

Figure 3. Jacobs' preference index of woodpecker foraging signs on trunks and limbs on each tree species. (For abbreviations of tree species see the legend of *Table 1*)

3. ábra Jacobs preferencia értékek a törzseken és az ágakon fafajok szerint. (A fafajok rövidítését lásd az *1. táblázat* jelmagyarázatánál)

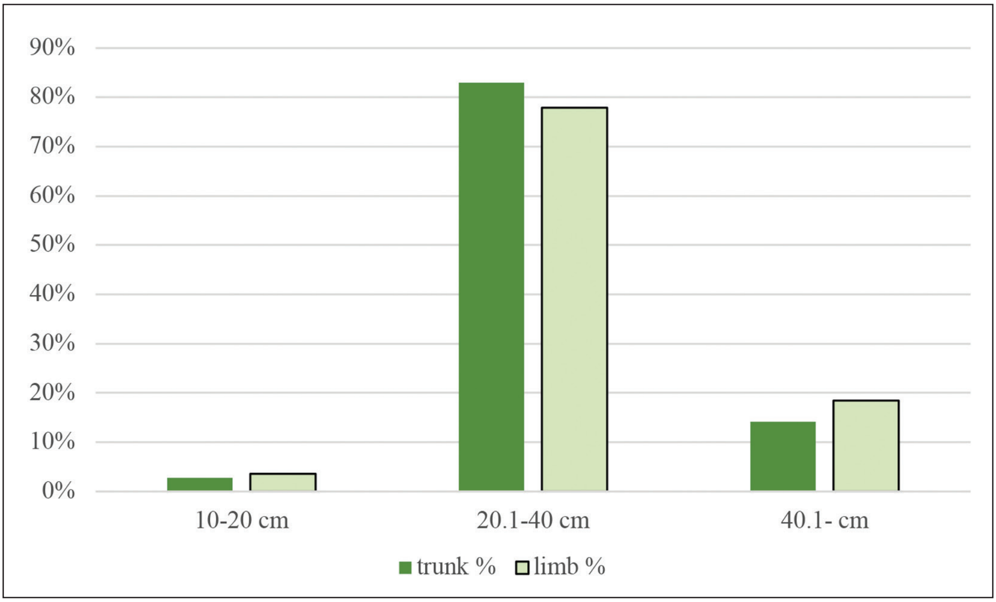

Figure 4. Percentage distribution of woodpecker foraging signs on trunks and limbs according to breast height categories

4. ábra A felmért harkály táplálkozási nyomok százalékos megoszlása a törzseken és az ágakon a megadott átmérőkategóriák szerint

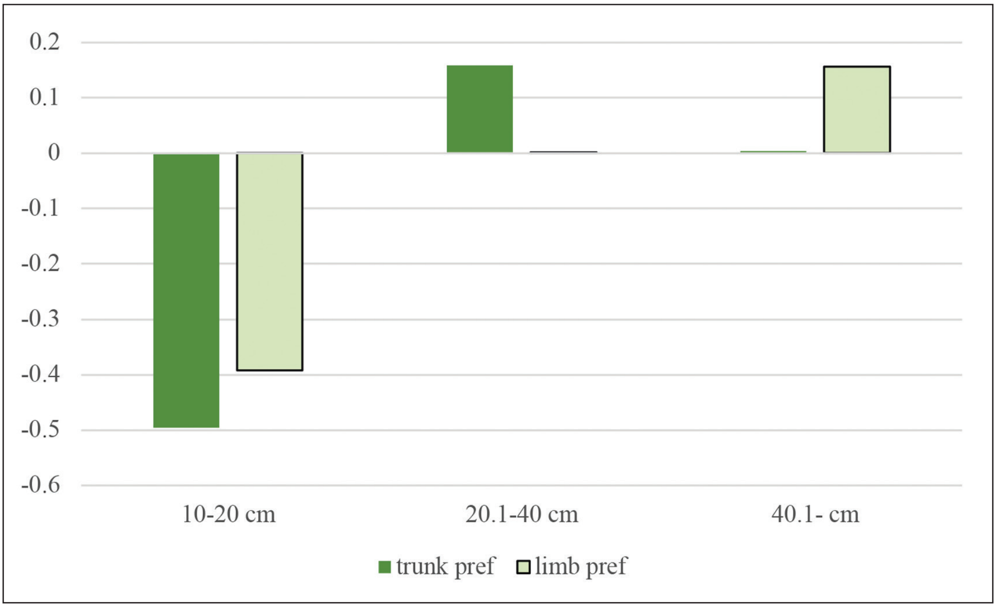

Figure 5. Jacobs' preference index of woodpecker foraging signs on trunks and limbs according to diameter at breast height categories

5. ábra Jacobs preferencia értékek a törzseken és az ágakon a megadott átmérőkategórák szerint

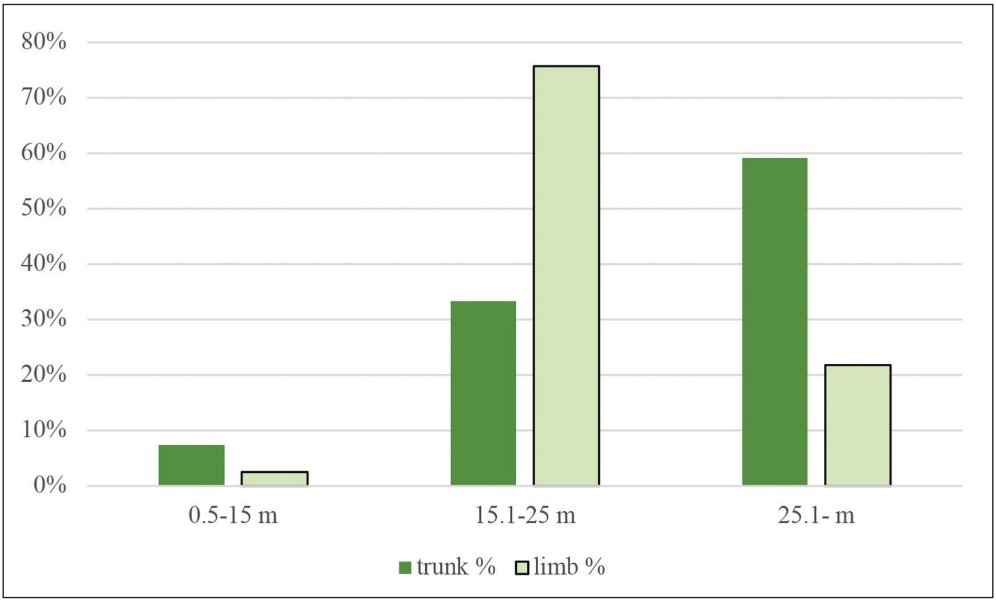

Figure 6. Percentage distribution of woodpecker foraging signs on trunks and limbs according to height categories

6. ábra A felmért harkály táplálkozási nyomok százalékos megoszlása a törzseken és az ágakon a megadott magassági kategóriák szerint

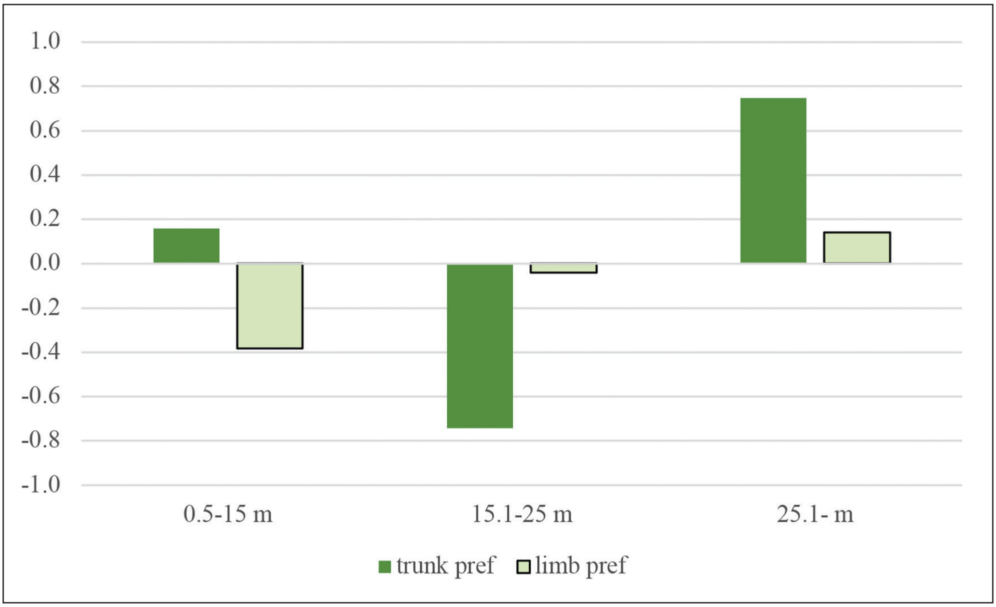

Figure 7. Jacobs' preference index of woodpecker foraging signs on trunks and limbs according to defined height categories

7. ábra Jacobs preferencia értékek a törzseken és az ágakon a megadott magassági kategóriákban

Foraging sign distributions (glmmTMB)

Regarding trunks, tree species significantly affected the occurrence of foraging signs. At the same time, interaction effects of the variables DBH and height also proved to be significant. On limbs, the effects of both tree species, DBH, and height were significant ($p<0.01$). The correlation here was stronger for limbs than for trunks *(Table 2)*.

Table 2. Effects of tree species, diameter and height on the presence of foraging signs on trees. Numbers in bold represent significant differences

2. táblázat A fafaj, az átmérő és a magasság hatása a táplálkozási nyomok előfordulására. A szignifikáns értékek félkövérrel szedettek

ANOVA Type=II, component=zi		**Chisq**	**Df**	**Pr(>Chisq)**
trunk	tree species	12.08	2	0.0024
	DBH	1.89	1	0.1696
	Height	3.50	1	0.0615
	species:DBH	0.85	2	0.6536
	species:Height	1.57	2	0.4565
	DBH:Height	11.13	1	**0.0009**
limbs	tree species	28.844	3	**<0.0001**
	DBH	19.92	1	**<0.0001**
	Height	9.92	1	**0.0016**
	species:DBH	5.47	2	0.0648
	species:Height	5.38	2	0.0677

Table 3. Effects of tree species, diameter, and height of trees on the amount of foraging signs present. Numbers in bold represent significant differences

3. táblázat A fafaj, az átmérő és a magasság hatása az előforduló táplálkozási nyomok mennyiségére. A szignifikáns értékek félkövérrel szedettek

ANOVA Type=II, component=cond		**Chisq**	**Df**	**Pr(>Chisq)**
trunk	tree species	0.57	2	0.7505
	DBH	0.37	1	0.5439
	Height	0.001	1	0.9702
	species:DBH	0.64	2	0.7251
	species:Height	2.96	2	0.2280
	DBH:Height	0.48	1	0.4883
limbs	tree species	28.50	2	**<0.0001**
	DBH_cm	0.001	1	0.9767
	Height_m	1.25	1	0.2643
	species:DBH	5.95	2	0.0511
	species:Height	2.76	2	0.2512

Table 4. Estimated probability of the presence of foraging signs and their relative amount when present on the different tree species. (For abbreviations of tree species see the legend of *Table 1*)

4. táblázat A táplálkozási nyomok előfordulásának és relatív kiterjedésének becsült valószínűségi értéke, amennyiben előfordul a vizsgált nyom, különböző fafajokra vizsgálva. (A fafajok rövidítését lásd az *1. táblázat* jelmagyarázatánál)

Species	**Trunk (presence of sign, %)**	**Limb (presence of sign, %)**	**Limb (relative area of sign, when present, %)**
QC	9.31 (2.18–32.1)^{b}	37.3 (31.5–43.5)^{a}	6.94 (6.18–7.78)^{a}
QR	4.23 (0.85–18.6)^{a}	55.8 (40.8–69.8)^{b}	12.11 (9.28–15.65)^{b}
QP	16.92 (4.25–48.3)^{c}	55.1 (48.4–61.6)^{b}	7.90 (7.12–8.76)^{a}

When a foraging sign occurred on a trunk, its area was not related to any of the studied predictors (tree species, DBH, height), while on limbs, only the tree species used had a significant effect on the area of signs *(Table 3)*. On trunks, the presence of foraging signs was most frequent on sessile oak, while on limbs, both sessile oak and pedunculate oak shared almost the same probability of presence. Regarding the relative area of signs, their extent, when present, was the highest on the limbs of pedunculate oak *(Table 4)*.

From the four different height categories, the following conclusions were drawn. The lower the tree, the greater the effect of diameter on the occurrence of signs. In greater height categories, the impact of diameter was moderate *(Figure 8)*. The results also showed that signs were more frequent on trunks with greater diameters and heights *(Figure 9–10)*.

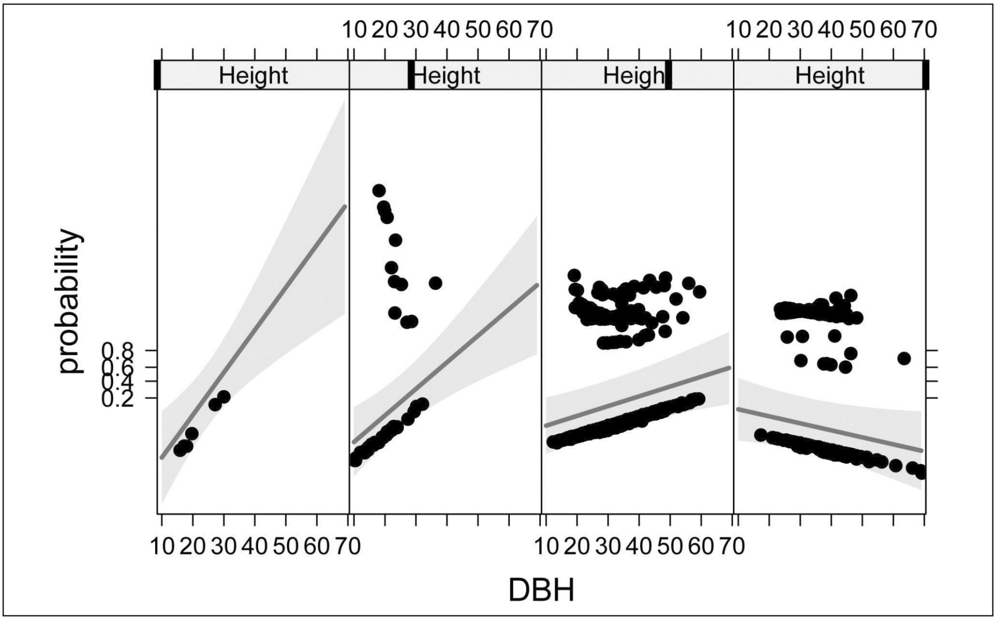

Figure 8. Interaction of the variables DBH and height with regards to the presence of foraging data on trunks

8. ábra A mellmagassági átmérő és a magasság interakciója a törzseken előforduló táplálkozási nyomok tekintetében

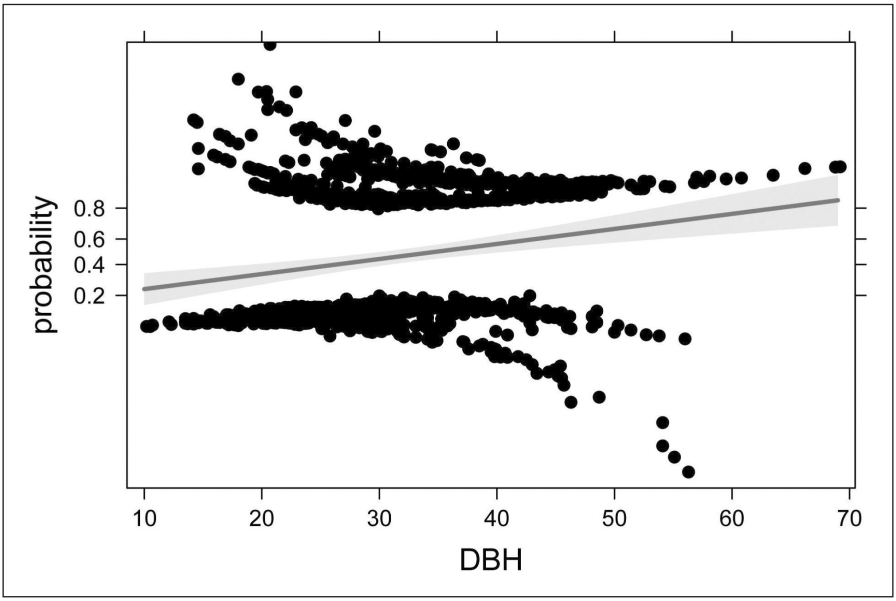

Figure 9. Linear correspondence (logit distribution) of DBH and the probability of presence of foraging signs on limbs

9. ábra A mellmagassági átmérő és a táplálkozási nyomok előfordulásának lineáris korreszpondencia vizsgálata a vizsgált ágak vonatkozásában

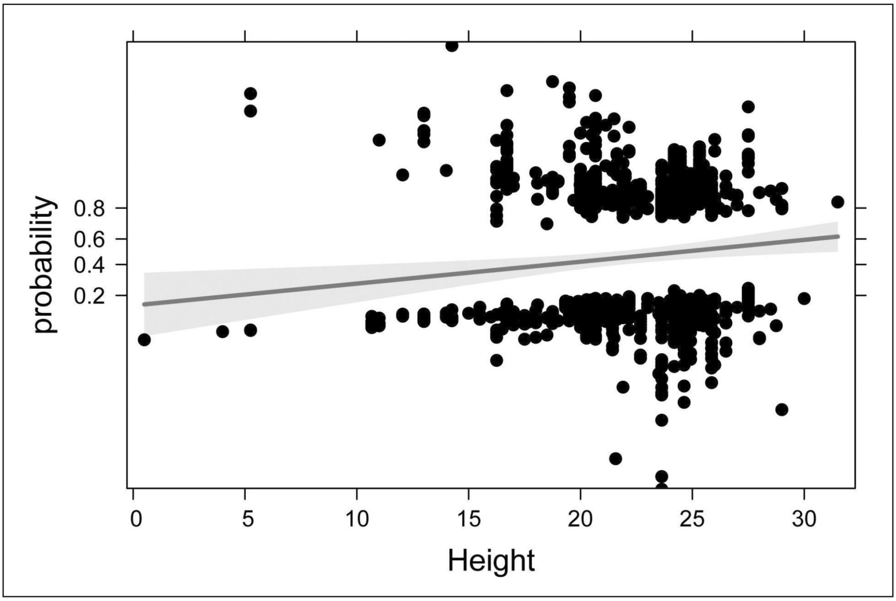

Figure 10. Linear correspondence (logit distribution) of height and the probability of presence of foraging signs on limbs

10. ábra A magasság és a táplálkozási nyomok előfordulásának lineáris korreszpondencia vizsgálata a vizsgált ágak vonatkozásában

Discussion

In the present study, we assessed managed, commercial forests, which are generally considered to be of little importance for nature conservation and biodiversity. Neither the structure nor the species composition is as rich in such forests as it is in natural ones (Tomiałojć *et al.* 1984, Kraigher *et al.* 2003, Bobiec *et al.* 2005, Christensen *et al.* 2005). Data from Central European managed deciduous forests are scarce (Mazgajski 1998, Kosinski 2006, Kosinski & Kempa 2007), compared to the number of similar research projects that have been carried out in so-called primeval forests such as Białowieża in Poland (Wesołowski *et al.* 2010, Walankievicz *et al.* 2011, Czeszczewik *et al.* 2015). Possibilities for comparison were, and are, therefore limited. Nevertheless, it is worth comparing our results with those that are available from unmanaged forests.

Similar to the observations by Kosinski (2006) and Pasinelli (2007), our results confirm that in mixed forests in Europe, woodpeckers mainly prefer oak species. This is due to the less diverse nature of the studied managed forests, primarily composed of oak species with a lower proportion of secondary tree species. However, woodpeckers, especially Great and Middle Spotted Woodpeckers, forage mainly on oak trees that have a fissured bark rich in arthropod fauna, providing an important food source even in forests where oaks are less dominant (Török 1990, Pasinelli & Hegelbach 1997, Kruszyk 2003, Kosinski 2006). Our results showed a relatively high preference for red oak. Red oak is an adventive species in Hungary, and thus, few insect ‘pest’ species (bark and wood-boring insects) use it (Rédei *et al.* 2011, Keserű *et al.* 2017), thus this phenomenon is noteworthy. In this study, woodpeckers utilized hornbeam only moderately. Studies in Białowieża showed that woodpeckers prefer to nest and forage on hornbeam, while other researchers stated they avoid this species (Hardersen 2004). The reason for this deviation could be that in primeval forests, the hornbeam trees used are older, more decayed, sizable, and hence often have substantial amounts of deadwood (Kosinski & Kempa 2007).

According to Roberge *et al.* (2008), the basal area/ha is one of the determining factors for foraging Middle Spotted and Great Spotted Woodpeckers, since they prefer older and wider trees.

In the framework of this baseline survey, we studied foraging on living trees, a subject which is generally uncommon in woodpecker-related research. Nonetheless, some previous studies have indicated that Great Spotted Woodpeckers are often associated with living trees (Török 1990, Farris & Zack 2005, Pasinelli 2007, Ónodi & Csörgő 2014, Ónodi & Winkler 2016, Kosiński *et al.* 2017).

Many papers discuss the relationship between snags and woodpeckers and the importance of deadwood to them (Angelstam *et al.* 2003, Farris & Zack 2005, Löhmus *et al.* 2010, Kosinski *et al.* 2017). Deadwood is usually scarce in managed forests, so our results might highlight some of the traits on trees that woodpeckers prefer if no deadwood material is available. We found stronger correlations for the canopy than for trunks, which may have been related to dead limbs being available in higher amounts in the canopy through the decaying processes initiated by wood-rotting fungi via mechanical damage e.g., windbreak (Gibbons & Lindenmayer 2002). Dead branches are crucial for, among other species, the Lesser Spotted Woodpecker (Roberge *et al.* 2008, Charman *et al.* 2010).

Nowadays, the vast majority of forests worldwide are managed in some way. To have diverse and stable ecosystems, it is often necessary to improve their natural characteristics through nature conservation management. To achieve this aim, it is important to diversify forests both structurally and compositionally. Conservationists can use various methods to create deadwood, new microhabitats and open canopy gaps, which can all help increase the diversity and abundance of a wide range of taxa: plants, fungi, saproxylic beetles, birds and mammals. Currently, such management activities are mostly employed in North America (Swallow *et al.* 1988, Hallett *et al.* 2001, Arnett *et al.* 2010, Kilgo & Vukovich 2014, Weiss *et al.* 2017, Sandström *et al.* 2019), although they are on the increase in Europe (Aulén 1991, Aszalós *et al.* 2020).

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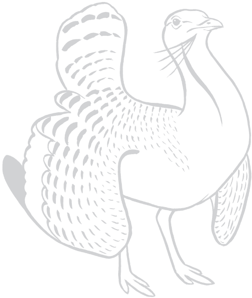

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The instrumental signals of the Eurasian Wryneck *(Jynx torquilla)*

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Abstract In a study of acoustic communication at seven nest cavities of Eurasian Wrynecks, sound recordings were made of ninety-one separate bursts of tapping. From Hungary in the east, and France in the west, tapping was heard both from inside cavities and at their entrances. Analysis of the tapping rhythms indicated two forms corresponding to different observed behaviour. They were never loud and were used exclusively in communication between breeding pairs. No functional significance was found in the only two brief examples of tapping fast enough to be described structurally as drumming.

Keywords: communication, tapping, drumming, nest cavities, wryneck, woodpeckers, spectrogram

Összefoglalás Ebben az akusztikus kommunikációval foglalkozó kutatásban hét nyaktekercs fészekodúnál 91 különálló kopogás egységről készült hangfelvétel. Keleten (Magyarország) és nyugaton (Franciaország) a kopogást az üregek belsejéből és a bejáratnál is lehetett hallani. A kopogás ritmusának analízise két formát mutatott ki, amelyek különböző megfigyelt viselkedéseknek feleltek meg. Sosem voltak hangosak, és kizárólag a költő pár közötti kommunikációban használták azokat. Nem találtunk funkcionális jelentőséget a csupán két rövid példa esetében, amikor a kopogás olyan gyors volt, hogy szerkezetileg dobolásként lehetett leírni.

Kulcsszavak: kommunikáció, kopogás, dobolás, fészekodúk, nyaktekercs, harkályok, spektogram

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Introduction

The Eurasian Wryneck *(Jynx torquilla)* is often regarded as an aberrant woodpecker, as in several aspects of its anatomy and morphology, it is the least typical of the eleven species in the Picidae family that breed in Europe. It is the only member, for example, that is truly migratory (most European breeding populations winter in sub-Saharan Africa), to have cryptic colouration, to have a relatively small head and long tail, to perch rather than climb, and to have a weak, passerine-like bill (Goodge 1972). Indeed, this species lacks many of the structural features typical of true woodpeckers (Picinae) that facilitate a physical ability to bore deep into wood to find invertebrate prey and fully excavate a nest cavity. The species is not sexually dimorphic and in most cases males and females are inseparable.

The Eurasian Wryneck has an exclusively Old-World distribution, occurring in parts of Europe, Asia and Africa (Gorman 2014). It is polytypic, with taxonomists recognising from four to seven subspecies (Winkler *et al.* 1995, del Hoyo & Collar 2014, Clements *et al.* 2019, Gill *et al.* 2020). Although the overall global population is suspected to be in decline, the species is not considered to be vulnerable or seriously threatened as it occurs over a vast range. Therefore, in the IUCN's Red List of species, it is categorised as *Least Concern* (BirdLife 2021).

Ringing recoveries in Europe suggest two probable migration routes, with birds from the north and west passing through Iberia and birds from further east travelling through Italy and the Balkans (Reichlin *et al.* 2009). The return to breeding areas in spring marks a peak of vocal activity, while both males and females seek potential nest sites. Persistent advertising, in the form of song, leads to the inspection of cavities by both birds and to courtship, which is accompanied by a range of soft, intimate calls (Ruge 1971). At this stage, although they do not excavate a complete cavity, birds may undertake some light, peripheral improvement of an existing one.

Some previous observers have suggested an instrumental function to tapping at the cavity entrance, such as when showing a potential nest site and when birds arrive for nest relief. Short (1982), referencing Witherby *et al.* (1938), wrote that the species sometimes drums 'woodpeckerlike, but weakly, slowly, and not audible at any distance', and 'drums weakly and infrequently in slow series' (1988). 'Drumming' inside the cavity as birds prepared to nest is mentioned by Puhlmann (1914). Tapping and 'drumming' on cavity walls and at the entrance are mentioned as taking place, when birds inspect and modify cavities, by Glutz von Blotzheim and Bauer (1994). The same authors also mention tapping with a rhythmic start that ends in a uniform roll on a branch away from the nest, but this behaviour is seldom observed and unpredictable (Gorman 2004). Wimmer and Zahner (2010) refer to soft 'tapping and drumming' when showing a nest cavity. More specifically, Schneider (1961) described four rolls ranging from six to ten strikes given by a bird at the entrance to a nest box in response to the arrival of a second bird.

Ruge (1971), however, defines such sounds as 'demonstrative tapping' or 'rhythmic tapping'. Due to the lack of any recorded examples, Eurasian Wryneck was not included in statistical comparisons of drumming by European woodpeckers (Zabka 1980, Florentin *et al.* 2016). In addition, Menzel (1968), Winkler *et al.* (1995) and González *et al.* (2002) do not detail any instrumental sounds for the species in their works. Whereas instrumental tapping has been described in all of the European Picidae (Cramp 1985), a behavioural comparison using measured examples, including Eurasian Wryneck, has yet to be published (Florentin *et al.* in prep.).

The aim of this paper was to analyse recent sound recordings of the instrumental signals produced by Eurasian Wrynecks with their bills, and to establish a better understanding of their structure and function. In addition, we sought to clarify the terminology used by previous authors on this subject, which in some cases is ambiguous.

Method and Materials

The recordings used in this study were made in two areas of Europe, Hungary and France. In Hungary, pairs were observed in the remnants of orchards bordering villages in the Bükk National Park (48.048°N 20.528°E). In France, pairs were observed in old false acacia

(Robinia pseudoacacia) scrub on a sheep grazed limestone plateau in the Parc Naturel Régional des Causses du Quercy (44.385°N, 1.342°E). Recordings were made in both areas from April to June covering the period of pair establishment and breeding. We placed microphones close to potential nest sites because this is the only reliable method of collecting instrumental sounds from this species. No examples of instrumental recordings for Eurasian Wryneck were found by searching other resources, such as the internet site xeno-canto.org. The only examples available came from a wide-ranging study of the acoustic signals of European woodpeckers (Turner unpub.).

We used a range of equipment: a pair of Sennheiser MKH 105 omnidirectional condenser microphones in an Atherstone 50×13cm parabolic reflector into a Kenwood DMC-G7R Minidisc recorder @ 44.1kHz/16bit (Atrac 4.5) and a pair of Sennheiser MKH 60 (short gun) condenser microphones into a Sound Devices 722 file recorder @ 44.1kHz/16bit. Reflector recordings were made at a distance of approximately seven metres and the open microphones were placed at about four metres from the nest cavity. Behaviour was observed though binoculars from between seven and ten metres. Sound editing was carried out using Cool Edit Pro II software, with spectrograms produced on Raven Lite (Cornell). Strike counts were extracted manually from spectrograms and average strike interval lengths were measured to the nearest millisecond, as employed in studies of drum-roll patterns (Zabka 1980, Florentin *et al.* 2016), using Microsoft Excel 2016.

We employed the following terms: ‘instrumental’ to mean a non-vocal sound used as a signal, ‘rhythmical’ to mean evenly spaced or smoothly accelerating/decelerating, ‘strike’ to mean an individual acoustic impact showing as a spike on a spectrogram, ‘burst’ to mean a distinct grouping of similarly spaced strikes having an average interval of more than 90ms, ‘roll’ to mean a distinct grouping of similarly spaced strikes having an average interval of less than 90ms. An average strike speed slower than this falls outside the range for drum-rolls encountered among European woodpeckers (Zabka 1980, Florentin *et al.* 2016, Turner 2020), and is therefore treated as instrumental tapping.

Gaps separating bursts of tapping were set at a minimum of 200 milliseconds, beyond which there was an audible pause in the tapping rhythm. Slower tapping speeds were associated with cavity modification. Sounds resulting from this activity typically had a more erratic strike rate in both rhythm and strength coupled with angled strikes sounding more like tearing, which resulted in double spikes on spectrograms. These sounds, paralleling those of excavation in other woodpeckers, were not treated as instrumental signals and were thus disregarded.

Results

Twenty-three recordings of sequences containing instrumental tapping were made, at five nest sites in France and two in Hungary, between 2001 and 2013 *(Table 1)*. Twelve of these were made at one nest in Hungary during a concentrated effort of 14 hours over seven days at the start of June 2007. Tapping bursts, consisting of the evenly or smoothly spaced strikes typical of instrumental signals, were given when both members of the pair were present:

Table 1. Dates and regions in which recordings of the Fast and Slow tapping rhythms were made. Number of bursts in brackets. In total, forty-two bursts of fast tapping were recorded at five nests and fifty of slow tapping at four nests, with both forms occurring at two nests

1. táblázat Gyors és lassú ritmusú kopogás felvételeinek dátuma és régiója. Az egységek száma zárójelben szerepel. Összesen negyvenkét egységről készült felvétel, gyors kopogás esetében öt fészeknél és ötven lassú kopogás esetében négy fészeknél, mindkét forma 2 fészeknél fordult elő

Year	2001	2003	2004	2006	2007	2013
Fast Hungary		6 May (3)			2/3 June (15)	
Fast France	8/13 May (14)	20/21 April (3)	12/18 April (5)	28 May (2)		
Slow Hungary		6 May (2)			2/3 June (47)	
Slow France						12 May (1)

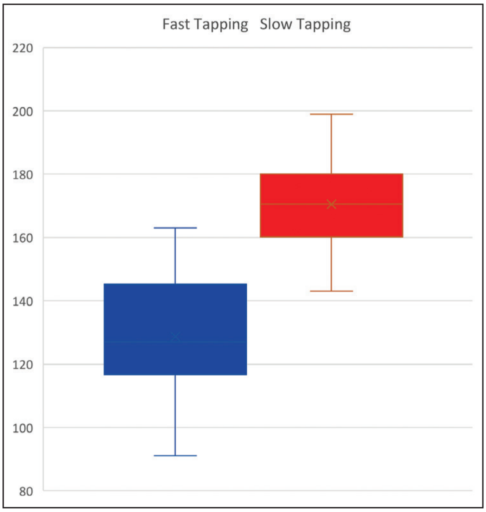

Figure 1. Average strike interval lengths (ms)
1. ábra Átlagos csapások közötti intervallumok hossza (ms)

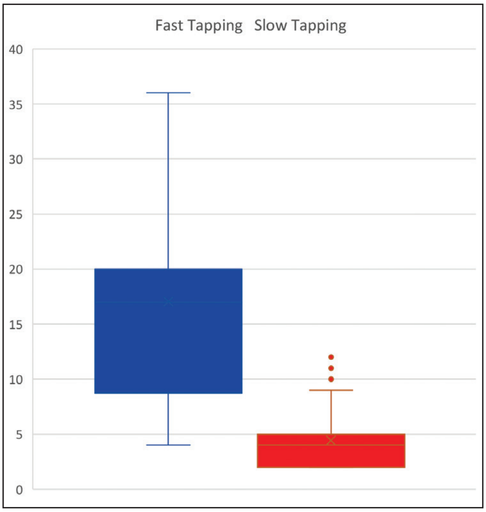

Figure 2. Average number of strikes per burst Fast tapping (n=42). Slow tapping (n=50). One exceptionally long burst of 65 strikes of fast tapping has been omitted

2. ábra A csapások átlagos száma egységenként
Gyors kopogás (n=42). Lassú kopogás (n=50). Egy kivételesen hosszú, gyors kopogás-egységet, amely 65 csapásból állt, kihagytunk

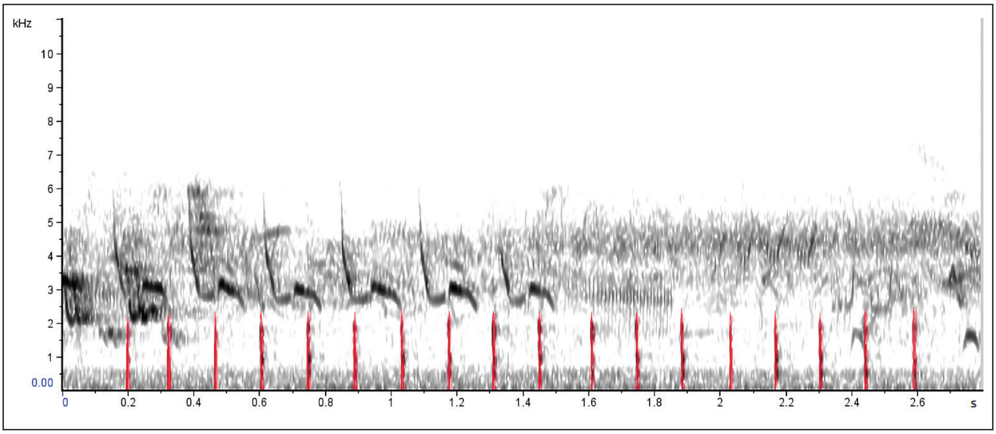

Figure 3. Burst of 18 strikes of fast tapping just inside the cavity, with a very regular interval length of 140 ms. Seven bursts were given in the sequence. France, 13th May 2001

3. ábra 18 csapásból álló gyors kopogás-egység az odú belsejéből, nagyon szabályos 140 ms intervallum hosszúsággal. Hét egység volt egymás után. Franciaország, 2001. május 13.

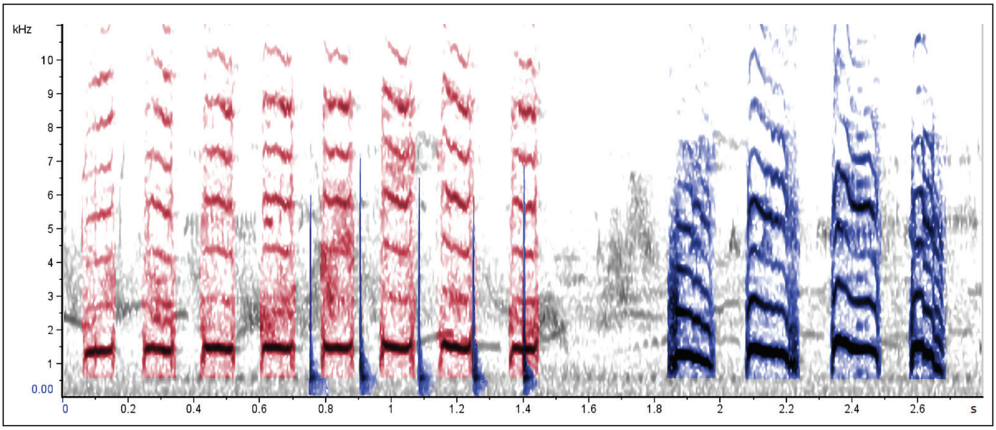

Figure 4. Short burst of slower tapping (5 strikes coloured blue, from 0.75 to 1.41 secs.) with average intervals of 162 ms given by one bird outside the cavity entrance during a song duet. The tapping coincides with the mate's song, heard from inside the nest cavity (8 elements, coloured red) and is immediately followed by the first bird's song (4 elements, coloured blue). This combination of slow taps and song came during a nine-minute recording that contained eighteen slow tapping bursts intermixed with thirty-five of excavation by the bird at the nest entrance. In the duet, this bird sang forty-two times and the bird inside fourteen times. Occasional 'vet' calls were given by both birds and one exceptionally soft roll was heard from inside towards the end

4. ábra Rövid egység lassú kopogásból (5 csapás, 0,75–1,41 s) 162 ms átlagos intervallum hosszal, egy madártól az odú bejáratán kívül egy duett során. A kopogás egybeesik a pár énekével, amit az odú belsejéből lehet hallani (8 elem, 0,6–1,44 s), amit azonnal követ az első madár éneke (4 elem, 1,8–2,7 s). Ez a kombinációja a lassú kopogásnak és éneknek egy kilenc perces felvételen szerepelt, amely tizennyolc lassú kopogás egységet tartalmazott összekeveredve harmincöt, az odú bejáratánál végzett vájással. A duett során ez a madár negyvenkétszer énekelt, míg a bent lévő madár tizennégyszer. Alkalmi „vet" hívóhangokat mindkét madár kiadott, és egy nagyon halk, dobpergés-szerű hang volt hallható belülről a vége felé

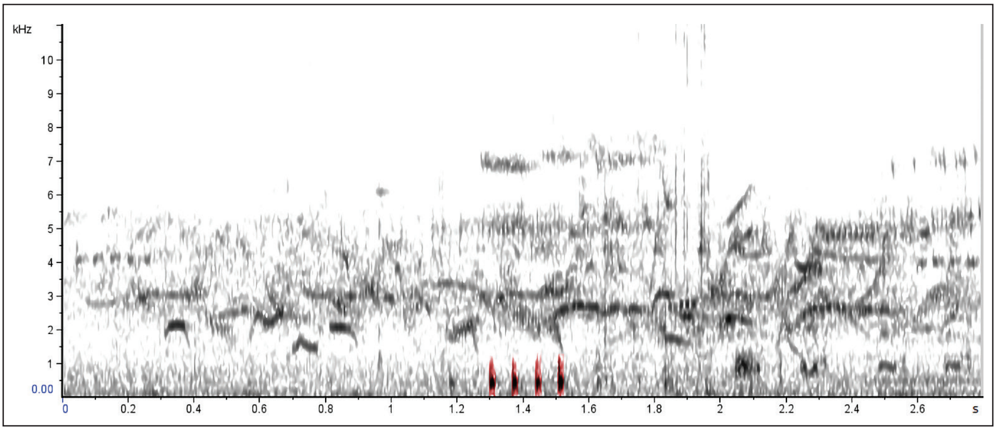

Figure 5. Soft roll, 4 strikes (from 1.3 to 1.52 secs) with average intervals of 69 ms. Given by a bird inside the cavity (from the same sequence as *Figure 4* Hungary, 3rd June 2007). Later in the morning, the first nestling calls were heard. This roll was one of only two recorded, both having only four strikes, with average interval lengths of 69 ms and 72 ms

5. ábra Halk dobpergés-szerű hang, 4 ütés (1,3–1,52 s) 69 ms átlagos intervallummal. Egy odúban lévő madár adta ki (ugyanabból a sorozatból, amelyikből a 4. ábra. Magyarország, 2007. június 3). A délelőtt során később lehetett hallani az első fióka hangokat. Ez a dobpergés-szerű hang az egyike volt a csupán kettő felvettnek, mindkettőben csak négy csapás volt, 69 ms és 72 ms intervallum hosszúsággal

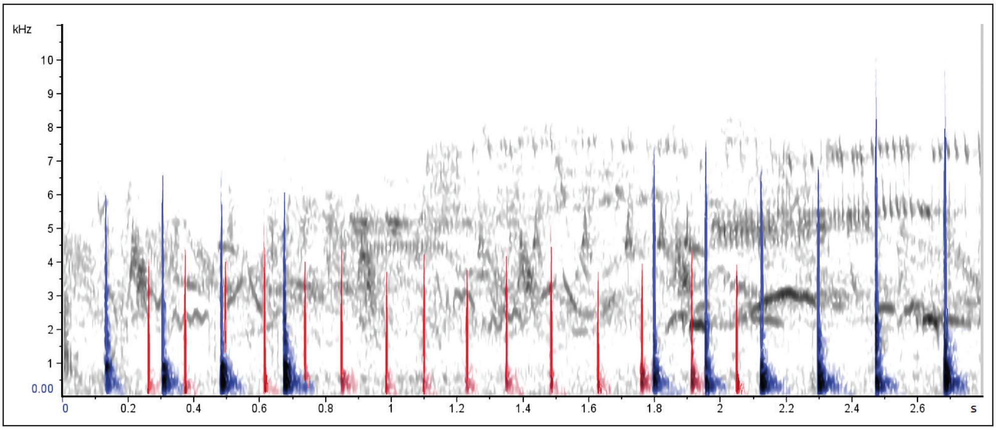

Figure 6. One bird tapping at the nest entrance (2 bursts - 4 & 6 strikes, coloured blue) at average strike intervals of 179 ms, while the mate replies with faster taps (15, coloured red) from inside the cavity at 126 ms. Hungary 3rd June 2007. The relationship between the structural difference of fast and slow tapping with the functional significance, one form given inside the cavity and the other outside, was clearly illustrated during a 'tapping-duet' where the bursts overlapped

6. ábra Egy madár kopácsol az odú bejáratánál (2 sorozat - 4 és 6 csapás, kék szín), a csapások közötti intervallum átlagosan 179 ms volt, míg a párja gyorsabb kopogással válaszolt (15, piros szín) az odú belsejéből 126 ms-mal. Magyarország, 2007. június 3. A gyors és lassú kopogás szerkezeti különbségének és funkcionális jelentőségének kapcsolata, az egyik az odú belsejéből, a másik kívülről leadva, világosan illusztrálva lett a „kopogás-duett" során, ahol a sorozatok átfedtek close to the cavity entrance, at the edge of the entrance, and inside the nest cavity. Two tapping speeds were identified *(Figures 1, 2)*.

Bursts of tapping were faster and longer when the pair were close to each other, forming a component of a courtship ceremony together with soft ‘vet’ and ‘graeb’ calls, and short, muted versions of the typical song of the species. Most of these fast bursts were given from deep within the nest chamber, with both birds present inside. However, one sequence was given by a bird just inside the entrance *(Figure 3).*

Nineteen recordings of courtship were made at the seven nest sites between April and June. Of these, twelve, from five of the sites, included fast tapping. In Hungary, a recording of a courtship sequence made at the time of egg-laying in mid-May, contained no tapping. However, in early June as eggs were starting to hatch, five sequences with tapping were recorded. By contrast, in France, five out of seven courtship sequences that contained tapping were recorded in the middle of April, possibly before eggs were laid. Overall, fourteen sequences containing bursts of fast tapping were recorded, eight in France and six in Hungary, of which five were at the nest in 2007.

All other examples of rhythmical tapping were given externally, by the nest entrance, in shorter, slower bursts. These appeared to signal the presence of the bird in the following situations: as the second bird was moving closer, to its mate already inside the nest *(Figures 4, 6)*, to its mate which had emerged, or following the ‘sgissgissgiss’ call when the mate did not respond. This call has been described as given in annoyance when a mate failed to appear for nest relief (Bussmann 1941). Nine sequences containing bursts of slower tapping were recorded, one at a nest in France and eight in Hungary, with seven at the nest in 2007.

An analysis of average strike intervals and number of strikes per burst enabled a comparison of relative speed and burst length for the two tapping rhythms (see *Figures 1*, *2*).

Double or triple taps were regularly heard but did not appear to have a different significance from the slower form and were frequently incorporated into longer sequences, with similar strike interval lengths to the longer bursts. One example of a double tap was given on exiting the cavity after feeding newly hatched young, and a triple tap was given in immediate response to its mate’s song.

Discussion

We found that breeding pairs of Wryneck used tapping as a means of communication at nest sites. Two speeds were observed, with a faster form given by one bird inside the cavity during courtship and a slower form given at the entrance. The statistics for strikes per burst from fast tapping inside the nest cavity may not fully reflect the length of the bursts, as these may have been shortened where some strikes were just too soft to hear or were obscured by sounds of other birds outside. Also, some ambiguity remains regarding the separation of slow tapping intended as a signal, from the generally looser pecking involved when Wrynecks modify a cavity entrance. That is, when they are combined in one sequence. This combination is not untypical of other woodpeckers, but the continuation right through to hatching was unexpected, except where it may have been a form of comfort behaviour.

In most European woodpeckers, instrumental tapping has been identified in two behavioural contexts; to signal either a potential nest site or, when a cavity is in use, readiness to changeover during excavation, incubation or brooding. Such communication is most ritualised in Black Woodpecker *(Dryocopus martius)* (Blume 1996), which taps rapidly inside the cavity during nest relief. For Eurasian Wryneck, the present study indicates that it uses the fast form as a component of a courtship ceremony, which may be performed at any time from early mating through to egg hatching and also occurs inside the nest. The slower form, given in short bursts, has a parallel with the 'nest showing' signals of so-called pied woodpeckers (Winkler & Short 1978, Blume & Tiefenbach 1997). The differences in observed behaviour confirm the significance of a functional separation of the two forms resulting from structural analysis (Zabka 1980) and see *Figures 5, 6* above. This is supported by the lack of any examples of slow tapping heard from inside the cavity.

It is interesting to speculate on the similarities between Eurasian Wryneck and the true (Picinae) woodpeckers regarding their evolutionary divergence. The theory that instrumental signals, including eventually drumming, may have evolved from the action of excavation (see for example, discussion in Zabka 1980) would suggest that separation occurred after the development of a strong bill and associated muscles. In this case, Eurasian Wryneck would be evolving away from a common, strong-billed ancestor. And yet, many similarities with the 'true woodpeckers' remain, as with some members of the *Melanerpes* genus of the Americas where mutual tapping, with one bird inside the cavity and one outside, is typical (Winkler & Christie 2002).

No substantive evidence was found of the use of drumming, either structurally fast enough to be considered drum-rolls, or functionally serving as signals. The two short rolls heard, barely matched our definition of the term and deviate from the relationship between structure and function associated with most other European woodpeckers (Turner 2020). One hypothetical explanation for the four-strike roll given inside the cavity could be as an intimate 'celebration' of egg hatching (as is done far more loudly, for example, by Black Woodpecker). While Eurasian Wryneck is capable of producing drum-rolls of sorts, we consider that with its fine-tipped, weak bill, it is not equipped to perform 'drumming' in the true sense, to loudly advertise territory as other woodpeckers do. Rather, it 'taps energetically with the bill within and around the nesting cavity' (Gorman 2004). We agree with Ruge *et al.* (1988) that Eurasian Wrynecks do not genuinely 'drum' and that the instrumental signals of this species are more accurately described as 'demonstrative' or 'rhythmical tapping'.

Conclusion

With statistical reliability limited by the available data, we believe that this study has nevertheless presented clear evidence of two tapping speeds performed by Eurasian Wrynecks at their nest sites. Both speeds were found to occur in the two distant areas of Europe where observations were made. The faster form, given inside the cavity during courtship, also had on average three times more strikes per burst than the slower form, given to signal presence at the entrance. Our close observations established that all of the examples recorded were given in communication between breeding pairs. One recording captured a pair tapping simultaneously, one at the faster speed inside and one at the slower speed outside. Two exceptionally soft and short rolls did not establish any clear behavioural significance and hardly justified the use of the term 'drumming' in the discussion of acoustic signals for this species. A better understanding of the function of instrumental tapping used by Eurasian Wryneck, and indeed other woodpecker species, would require a more continuous observation of one or more pairs throughout their breeding cycle.

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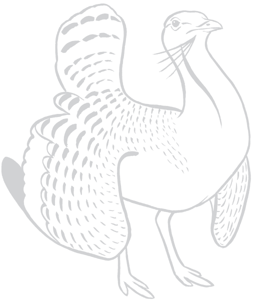

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Diet of Long-eared Owl and Common Kestrel in an urban landscape (Ukraine)

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Abstract In the present study we performed a comparative dietary analysis of two predatory birds, the Long-eared Owl *(Asio otus)* and the Common Kestrel *(Falco tinnunculus)* in the district of Lviv city. We found that the Long-eared Owl and the Common Kestrel are typical small mammal specialists within the urban ecosystem. Considering the abundance and biomass of prey, small mammals comprise 98.4% of the Long-eared Owl's diet. The species composition of mammals coincides almost 50% in the food intake comparison of the two birds. It has been established that the main prey of both species is the Common Vole *(Microtus arvalis)*. The diet of the Common Kestrel is more varied, compared to the Long-eared Owl, due to the consumption of different species of insects (families Gryllotalpidae, Tettigoniidae, Carabidae and Scarabaeidae), reptiles and birds. This result suggested that dietary plasticity of the Common Kestrel facilitate successful adaptation to the urban landscape. The Long-eared Owl is more narrowly specialized in feeding on murine rodents, which reduces the trophic competition between the two predatory birds and allows the coexistence of two predators in the urban ecosystem.

Keywords: diet analysis, urban ecosystem, small mammals, Common Kestrel, Long-eared Owl

Összefoglalás Jelen tanulmányban Lviv város környezetében jellemző két ragadozó madár, az erdei fülesbagoly *(Asio otus)* és a vörös vércse *(Falco tinnunculus)* táplálkozásának összehasonlító elemzését végeztük el. Megállapítottuk, hogy Lviv város ökoszisztémájában a vörös vércse és az erdei fülesbagoly tipikus kisemlős specialista fajok. Mind az abundancia, mind a biomassza tekintetében az erdei fülesbagoly étrendjének 98,4%-át kisemlősök tették ki. A kisemlős összetétel csaknem 50%-ban megegyezett a két madárfaj táplálék fogyasztásának összehasonlításában. Megállapítást nyert, hogy mindkét faj fő zsákmánya a mezei pocok *(Microtus arvalis)*. Az erdei fülesbagollyal ellentétben a vörös vércse étrendje a különféle rovarfajok (Gryllotalpidae, Tettigoniidae, Carabidae és Scarabaeidae családok), hüllők és madarak fogyasztása miatt változatosabb. Ez a vörös vércse táplálkozási plaszticitását jelzi, amely az urbanizált tájban megkönnyíti a sikeres adaptációt. Az erdei fülesbagoly inkább az egérfélék fogyasztására specializálódott, ami csökkenti a két ragadozó madár közötti trofikus versengést, és a városi ökoszisztémában lehetővé teszi együttélésüket.

Kulcsszavak: táplálék vizsgálat, városi ökoszisztéma, kisemlősök, vörös vércse, erdei fülesbagoly

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Introduction

The contemporary state of the world's fauna can be described by unprecedented scales of its changes, which are mainly caused by an anthropogenic factor (Zagorodniuk 2006). Within the last decades, we were able to observe intensified development of disturbed human environments. This significantly changed natural habitats (Dziemian *et al.* 2012), but it could also create new ecological niches for many species (Luniak 2004, Żmihorski & Rejt 2007). Birds are exposed to significant ecological disturbance. It mainly concerns the natural populations of predatory birds, as one of the most vulnerable taxa that are forced to change their behavior and spatial distribution, which is mainly reflected in their foraging – a primary physiological demand of the living organism.

The topic of changes in fauna is being actively discussed and is developing in academia. Moreover, this topic is commonly ignored in Ukraine, so that the lack of information exists in this field (Zagorodniuk 2006).

The Long-eared Owl and the Common Kestrel, as abundant raptors were chosen as model species to reveal the issues of their foraging behavior (Bokotey 2008). Birds of prey are well-known for their dependence on the availability of prey, which may be affected by different factors: weather conditions, structure and height of the vegetation cover and agricultural activity (Tulis 2015). The hunting territories of both species are similar to some extent. Studying the diet of both species (in the future) could help to reveal the consequences of the anthropogenic pressure on both nocturnal and diurnal predators. The Long-eared Owl is one of the species of predatory birds that can be found not only in rural areas but also in big cities (Sharikov 2005). It is typically observed in forests, shrubs, parks and gardens (Fesenko & Bokotey 2002). The diet of this owl is well studied both troughout Europe and in Ukraine (Marti 1976, Mikkola 1983, Bertolino *et al.* 2001, Kondratenko *et al.* 2001, Polishchuk, 2008, Zaitseva & Hnatyna 2009), which can be explained by its widespread occurrence and high abundance (Gavrilyuk *et al.* 2009, Drebet 2013), but no special trophic studies of this species were conducted in Lviv.

As a common rule, the diet of the Long-eared Owl tipically consists of 1–3 small mammal species that belong to the Arvicolidae family (Cherkashchenko 1960, Marti 1976, Drebet 2009, Stasiak *et al.* 2012). Despite this fact, the latest updates show that this species performs trophic adaptations, which lead to the increase of the consumed prey diversity in Europe (Bertolino *et al.* 2001). For sedentary species, adjustment to new trophic conditions can be crucial during winter when food availability decreases (Żmihorski & Rejt 2007). Therefore, studying the changes in the diet with regards to seasonal and temporal patterns remains important, especially given the rapid changes in habitats (Drebet 2011).

The Common Kestrel is the most abundant bird of prey in urban habitats of the Western Palearctic (Cramp & Simmons 1980). Most of the nesting pairs of urban colonies are located on high buildings adjacent to parks or other greenery, especially on the periphery of a city with developing construction. However, open habitats with a mosaic of small forests are the typical habitat for this species in the wild (Zubarovsky 1977). Some adaptive traits in the biology and ecology of this species, such as the diet, have changed after the invasion to urban ecosystems (Rejt 2007). The most obvious reactions of raptors to food shortages are expanding the diet to alternative prey (Korpimäki 1986, Reif *et al.* 2001, Riegert *et al.* 2007). Urban Kestrels have an excellent opportunity to feed on birds, as their availability does not usually change markedly between years (Riegert *et al.* 2007).

The aim of this work is to reveal the diet, size of the prey, and foraging strategy of the Long-eared Owl and the Common Kestrel in Lviv and to compare them.

Materials and Methods

The research was conducted in the territory of Lviv, one of the largest cities in Ukraine. It is located in the forest-steppe region of the western part of the Volyn-Podilska Upland, in the valley of the Poltva river (Vistula/Baltic Sea basin) and on the slopes of the surrounding hills (Gerenchuk 1972). The built-up area of the city with parks and forest parks surrounded by buildings (ecological boundaries of the city) is 66.7 km^2 (Bokotey 2008). Materials for this study were collected in the territory of Halych, Lychakiv, Sykhiv districts and on the outskirts of the city (near the village of Solonka): central, eastern, south-eastern and southern parts of the city, respectively.

We carried out the field collection of pellets and prey residues during the nesting and non-nesting periods in resting places, under perches, and also in the birds' nests and under them. This method is widely used to study the spectrum of bird feeding. Pidoplichka (1932, 1937) was the first scientist in Ukraine who studied pellets to describe the diet of birds of prey. This method has become popular in the work of other researchers (Cherkashchenko 1960, Zaitseva & Hnatyna 2009, Stasiak *et al.* 2012 and many others) and replaced the analysis of stomach contents of birds, which requires the removal of animals from native habitat. Nowadays, the analysis of pellets of birds of prey has become relevant again due to the necessity of using cheap and non-invasive methods of material collecting without disturbing populations (Atamas 2002, Kuznetsov & Kondratenko 2006, Zaytseva & Drebet 2007). In addition, pellet analysis allows to study the trophic relationships between predators and prey in different ecosystems (Atamas 2004).

The bigger part of pellets of the Long-eared Owl was collected in daytime resting places in the winter-spring period and also in early October of 2015. October collection contained pellets from both autumn and summer period, which allows us to assess the feeding of this species throughout the year. The Long-eared Owl uses trees for the day rest (the norway spruce *Picea abies* and the northern white-cedar *Thuja occidentalis*), as the crown protects birds from the adverse effects of weather conditions (e.g. wind, precipitation). The trees were located in the area of a horse racetrack. Overall, 665 Long-eared Owl pellets were collected and analyzed, and 1618 food items were identified.

The pellets of the Common Kestrel were collected from March to August in 2014–2015, which represents the entire period the birds stayed in the nesting area (kestrels stay in Lviv in winter in rare cases). Overall, 527 pellets and prey remains of this species were collected and analyzed. Altogether, 599 food items were identified.

Identification of small mammal species was performed according to the characteristics of the structure of the skull, jaws, teeth and dentition (for mammals); feathers, skeletal remains, as well as the shape and size of the beak (for birds); head shields and scales (for reptiles); the presence of forewings, wings and chitinous covers (for insects) (Vinogradov & Argyropulo 1941). The biomass value was obtained from literature sources (Pucek 1984, Romanowski 1988, Dietz *et al.* 2009, Kitowski 2013).

We calculated the percentage ratio in the total dietary biomass for each food item and the frequency of their occurrence. The average body weight used to estimate the biomass of prey is presented in *Table 1*, while for invertebrates, the average weight is 0.5 g for each specimen. To compare the mean biomass of prey we used it's abundance weighted by predicted biomass. Since the abundance of a certain prey can be expressed as a proportion of this prey in the diet of a raptor, it is possible to apply a binomial test to compare two proportions (Crawley 2007), which was done both for abundance and biomass data.

All calculations were made using R programming language (R Core Team 2020).

Results

According to the pellet analysis, it was established that the basis of the diet of both studied species within the city of Lviv are small mammals. In contrast, insects are rare in the diet of the Long-eared Owl, and reptiles have not been observed *(Table 1)*. However, these species play a significant role in the feeding of the Common Kestrel in certain periods (see below). Small mammals comprise 98.4% of the diet of the Long-eared Owls in number and biomass. 13 species of small mammals were identified in total. The most abundant species were *Microtus arvalis* (75.6% in number and 72.1% in biomass), *Microtus agrestis* (5% and 5.8%), *Apodemus agrarius* (5.1% and 4.4%), *Sylvaemus sylvaticus* (4.3% and 4.3%) and *Nyctalus noctula* (3.6% and 4.7%). Birds (5 species) amount to 1.4% in number and 1.6% in biomass. Insects, particularly *Melolontha melolontha*, were found in only four pellets (a total of 4 individuals). They are less than 1% in both quantity and biomass. It has been found that the average weight of the Long-eared Owl's prey is 30.2 g (range 0.5–238 g).

According to our data, mammals comprise 71.8% by abundance and 79.9% by biomass in the diet of the Common Kestrel. 6 species of mammals were identified in the analysis of pellets. The main prey among them was *Microtus arvalis* (68.9% by abundance and 75% by biomass), followed by other rodents: *Microtus agrestis* (1.3% and 1.6% respectively), *Apodemus agrarius* (1% and 0.9% respectively). Birds (7 species) amounted to 4.4% of the diet by quantity and 14.7% by biomass. Reptiles also play a significant role in the nutrition of the Common Kestrel in the study areas (6.9% in number and 5% in biomass), which are represented by only one species – *Lacerta agilis*. Insects belonging to the orders Orthoptera and Coleoptera have also been found in the diet of the Common Kestrel. The members of the families Gryllotalpidae and Tettigoniidae among the Orthoptera and representatives of the families Carabidae and Scarabaeidae among the beetles were found in the diet of the Common Kestrel. Insects comprised 16.8% of the diet in terms of quantity, but only 0.5% in biomass. The average weight of the prey was 52 g (range 0.5–238 g).

It is notable that some individuals of the Common Kestrel can consume some anthropogenic inedible materials such as styrofoam and cotton, which were found in 30 samples; in 2 cases

Table 1. Diet composition of *Asio otus* and *Falco tinnunculus* in the area of Lviv. MNI – minimum number of individuals

1. táblázat Az erdei fülesbagoly és a vörös vércse táplálék-összetétele Lviv város területén. MNI – minimum ismert egyedszám

number and frequency of occurrence				**Object of nutrition, Species**	**Average body weight, g**	**biomass of the food object**			
Asio otus		***Falco tinnunculus***				***Asio otus***		***Falco tinnunculus***	
MNI	**MNI %**	**MNI**	**MNI %**			**MNI g**	**MNI g %**	**MNI g**	**MNI g %**
9	0.6	0	0.0	*Micromys minutus*	8	72	0.2	0	0.0
83	5.1	7	1.0	*Apodemus agrarius*	17	1411	4.4	119	0.9
18	1.1	0	0.0	*Sylvaemus tauricus*	31	558	1.7	0	0.0
69	4.3	1	0.1	*Sylvaemus sylvaticus*	20	1380	4.3	20	0.2
28	1.7	0	0.0	*Sylvaemus uralensis*	19	532	1.6	0	0.0
11	0.7	0	0.0	*Mus musculus*	15.5	170.5	0.5	0	0.0
4	0.2	1	0.1	*Rattus norvegicus*	238	952	2.9	238	1.9
222	13.7	9	1.3	Muridae		5075.5	15.7	377	3.0
1227	75.6	496	68.9	*Microtus arvalis*	19	23313	72.1	9424	75.0
81	5.0	9	1.3	*Microtus agrestis*	23	1863	5.8	207	1.6
1308	80.6	505	70.1	Arvicolidae		25176	77.9	9631	76.7
4	0.2	3	0.4	*Sorex araneus*	8	32	0.1	24	0.2
1	0.1	0	0.0	*Sorex minutus*	3.5	3.5	0.01	0	0.0
2	0.1	0	0.0	*Crocidura leucodon*	8	16	0.05	0	0.0
7	0.4	3	0.4	Soricidae		51.5	0.2	24	0.2
59	3.6	0	0.0	*Nyctalus noctula*	25.5	1504.5	4.7	0	0.0
1596	98.4	517	71.8	MAMMALIA		31807.5	98.4	10032	79.9
5	0.3	14	1.9	*Parus major*	17.5	87.5	0.3	245	2.0
0	0.0	4	0.6	*Cyanistes caeruleus*	10.5	0	0.0	42	0.3
0	0.0	2	0.3	*Turdus* sp.	94	0	0.0	188	1.5
12	0.7	4	0.6	*Passer domesticus/montanus*	24.5	294	0.9	98	0.8
1	0.1	1	0.1	*Emberiza citrinella/schoeniclus*	23	23	0.1	23	0.2
3	0.2	0	0.0	*Pyrrhula pyrrhula*	27.5	82.5	0.3	0	0.0
1	0.1	1	0.1	*Carduelis carduelis*	16	16.0	0.05	16	0.1
0	0.0	6	0.8	*Columba livia* juv	205	0.0	0.0	1230	9.8
22	1.4	32	4.4	AVES		503.0	1.6	1842	14.7
0	0.0	50	6.9	*Lacerta agilis*	12.5	0	0.0	625	5.0
0	0.0	50	6.9	REPTILIA		0	0.0	625	5.0
4	0.2	121	16.8	INSECTA	0.5	2.0	0.01	60,5	0.5
1622	**100**	**720**	**100**	**In general**		**32312.5**	**100**	**12559.5**	**100**
				Number of pellets		**665**		**527**	

the pellet was entirely styrofoam. But those cases are related only to one pair of raptors which made its nest in a cavity isolated by a sheet of styrofoam.

The overlap of trophic niches in these two species was considerable. Jaccard index was 0.45, but it represents only the similarity of presence/absence data. We also used Bray-Curtis index, which showed that Jaccard index was relevant in our case: this index shows 0.45 overlap by abundance of prey and 0.46 overlap by its biomass.

The Long-eared Owl prefers to hunt bigger prey than the Common Kestrel *(Table 2)*. This slightly contrasts with the average body mass of prey objects: there is a bigger biomass in

Table 2. Comparison of food item abundance and biomass in the diet of the Long-eared Owl and the Common Kestrel in Lviv (Ukraine)

2. táblázat Az erdei fülesbagoly és a vörös vércse táplálék-összetételének összehasonlítása a táplálékfajok abundanciája és biomasszája alapján Lviv városban (Ukrajna)

Prey	**Binomial proportion test**			
	Abundance		**Biomass**	
	χ^2	**p**	**χ^2**	**p**
Micromys minutus	2.765	0.096	27.228	<0.001
Apodemus agrarius	22.768	**<0.001**	132.681	**<0.001**
Sylvaemus tauricus	6.820	**0.009**	222.798	**<0.001**
Sylvaemus sylvaticus	28.352	**<0.001**	516.038	**<0.001**
Sylvaemus uralensis	11.412	**0.001**	212.224	<0.001
Mus musculus	3.654	0.056	66.508	**<0.001**
Rattus norvegicus	0.003	0.954	42.048	**<0.001**
Microtus arvalis	16.733	**<0.001**	9.202	**0.002**
Microtus agrestis	18.555	**<0.001**	360.828	<0.001
Sorex araneus	0.067	0.796	5.071	**0.024**
Sorex minutus	0.000	1.000	0.343	0.558
Crocidura leucodon	0.036	0.850	5.029	**0.025**
Nyctalus noctula	25.952	**<0.001**	616.553	<0.001
Parus major	14.188	**<0.001**	335.558	**<0.001**
Cyanistes caeruleus	5.922	**0.015**	102.477	**<0.001**
Turdus sp.	1.791	0.181	472.400	**<0.001**
Passer domesticus/montanus	0.070	0.791	2.087	0.149
Emberiza citrinella/schoeniclus	0.000	1.000	9.525	**0.002**
Pyrrhula pyrrhula	0.295	0.587	31.406	**<0.001**
Carduelis carduelis	0.000	1.000	6.320	**0.012**
Columba livia juv	10.254	**0.001**	3186.085	<0.001
Lacerta agilis	109.479	**<0.001**	1594.595	**<0.001**
Insects	261.619	**<0.001**	140.633	**<0.001**
Styrofoam	21.273	**<0.001**		
Cotton	5.922	**0.015**		

prey objects of the Common Kestrel than of the Long-eared Owl. But after the exclusion of non-typical rare objects (*Rattus norvegicus*, *Turdus* sp., *Columba livia* juv) we can easily see that a typical prey of the Long-eared Owl is bigger (18.2 g) than of the Common Kestrel (14.7 g). Taking into account the abundance of prey, the typical prey unit in the Long-eared Owl was 33.25±22.44 g vs. 18.37±21.75 g in the Common Kestrel. It is found that abundances of 16 prey types *(Table 2)* out of 25 are significantly different in the diets of the two species. But the comparison of the proportion of the prey in the diet by abundance shows that 14 prey types are significantly different and almost all proportions by biomass (except *Sorex minutus* and *Passer* sp.) are different in the diets of the Long-eared Owl and the Common Kestrel *(Table 2)*. Both *Sorex minutus* and *Passer* sp. were presented in extremely low numbers *(Table 1)*, so this result more probably indicates that both the Common Kestrel and the Long-eared Owl consume these preys extremely rare. More generally, the above results imply that the diets of the two species of raptors do not overlap by biomass proportions.

Discussion

The results of analysis of the Long-eared Owl's foraging preferences in Lviv fit a considerable body of literature, which shows that this owl is a specialist in catching small rodents such as *Microtus* sp., but those preferences could change throughout the year (Polishchuk 2008). A huge part of the Long-eared Owl's diet consists of *Microtus arvalis*, which is a typical species of rural landscapes, agricultural lands and cities. Despite the fact that the abundance of this species is lower in urban areas, it is still the most abundant in the owl's diet (Harmata 1969, Wendland 1984, Romanowski & Zmihorski 2008, Riegert *et al.* 2009, Drebet 2011). The diversity of murines in the diet of the Long-eared Owl can be explained by the fact that our study sites were located near a horse stable, which provides an extremely suitable habitat for those rodents. Also, the landscape is heterogeneous due to a high diversity of trees and shrubs and the presence of open lands patches, which provide a habitat for different species of rodents and a good location for hunting (Marzluff & Rodewald 2008).

It is a well-established fact that the number of bats in the Long-eared Owl's diet is normally low (Zaytseva & Drebet 2007, Drebet 2013). Because the bats are the rare prey of the owls, the assessment of their relations could be complicated. We have observed cases of bats' presence in the diet of the Long-eared Owls, but those cases were rare which points out the fact that such events are occasional. The only one bat species – *Nyctalus noctula* – comprised only 3.6% of the Long-eared Owl's diet. We assume that those pellets that were collected in March contained the *Nyctalus* bats that were predated during the fall because this species has a considerable hibernation period. We think that a big number of preyed bats are related to several specialized individuals who learned how to hunt near the exit from the mother colony of bats. Some cases of in-air hunting are known, but they are rare (Polishchuk 2008). It is noticeable that the wintering sites were located in the same places from year to year, which are close to the bats' colonies. Although the bats are not thought to be considerable in the owl's diet in Lviv, sometimes they can be locally abundant in pellets of the Long-eared Owls near mother colonies and/or in periods of fall flocking. Considering those facts, we confirm that bats are random and not regular prey of the Long-eared Owl.

The insects are also rare in the owl's diet. In particular, insects are completely absent in the diet of this species from the territory of České Budějovice (Riegert *et al*. 2009). In our research area, insects can be found during springs and summers. Only *Melolontha melolontha* can be observed in the Long-eared Owl's diet rarely (0.2%). Also, birds are rare but regular prey (1.4%) of the owls, so those prey are sporadic.

The diet of raptors may change when they inhabit urban areas. For example, Kestrels in large cities often enrich their diet with birds (Witkowski 1962, Beichle 1980, Romanowski 1996). However, we did not observe such a switching in Lviv. The proportion of birds was consistently low, as in Kestrels in České Budějovice (Riegert *et al.* 2009). The diet of the Common Kestrel consists mostly of small rodents similarly to the Long-eared Owl. Birds, reptiles, and insects are minor prey for this falcon. We revealed that according to our data collected in 2014, 72.8% of the prey was *Microtus arvalis* and 65.7% in 2015. There are much lower abundances of *Microtus agrestis* (2.8%), *Sylvaemus sylvaticus* (0.3%), *Apodemus agrarius* (0.3%) in the Common Kestrel's diet.

The percentage of insects was twice higher in 2015 compared to 2014 (10.5% vs. 21.9%) in the Common Kestrel's diet. The numbers of birds were the same compared to 2014, but we have not observed *Microtus agrestis* and *Sylvaemus sylvaticus* and have observed *Sorex araneus* (n = 3) instead. Artificial materials such as cotton and styrofoam were not observed, which can be explained by nest site features of the defined pair mentioned above.

The analysis of the Common Kestrel's pellets collected in 2014–2015 allows us to assume that the diet of this falcon species is broad: at least 15 types of prey were observed *(Table 1)*. We divided all those types into 3 main groups: major, additional, and occasional. *Microtus arvalis* is identified as a major prey (68.9%); insects, birds, and reptiles are thought to be additional prey (16.5%, 4.4%, and 6.9%, respectively), which are used in cases of obstacles to feed on major preys or in cases of low abundances of *Microtus arvalis* (Riegert & Fuchs 2004). Temporal availability changes in some types of resources could be one more reason to use additional resources: for example, there are distinct spikes in *Melolontha melolontha* abundances in May. Other resources are those which comprise less than 0.5% and are occasional.

The Common Kestrel's diet is more diverse compared to the Long-eared Owl, because it includes several species of insects (from families of Gryllotalpidae, Tettigoniidae, Carabidae, Scarabaeidae) and reptiles. It shows the reduction of the hunting specialization in the Common Kestrel. But the role of insects in the Common Kestrel's diet is overestimated, in our opinion: many researchers calculate abundance only, which leads to overestimations because of a big number of exoskeletons fragments (elytron and other chitin-rich parts) in pellets. Despite this fact, the biomass percentage of insects is much lower: 16.8% by abundance and 0.5% by biomass according to our data.

Riegert *et al.* (2009) examined the possible relationship between the distance from a nest to the city centre and the proportion of voles in the diet of the two species. The Kestrel diet was not markedly influenced by distance, but for Long-eared Owls, an increasing distance was associated with an increasing dietary proportion of voles. The difference between the two species is confirmed by results on hunting activities revealed by telemetry and wing-tagging. Kestrels almost exclusively hunt in rural areas (Riegert *et al.* 2007), Long-eared Owls often hunt in edge habitats within the city area (Lövy 2007). Such habitats host a high diversity of small mammals, especially Muridae (Briner *et al*. 2005, Suchomel & Heroldová 2006).

Thus, the diets of both raptors consist mostly of small mammals, birds and insects in the urban landscapes, but the diet of the Common Kestrel also includes reptiles (7%), which is a considerable addition. 98.4% of the Long-eared Owl's diet is small mammals. Only 6 out of 13 species registered are common in the diets of both species.

Selectivity

It is known that the percentage of rodents in the diet of the predator, in part, depends on their numbers. In polyphagous predators, there is a relationship between the large number of rodents and their share in the diet of predators. However, specialized predators consume the high proportion of desired prey even with low prey numbers (Andersson & Erlinge 1977, Romanowski 1988).

The Long-eared Owl, like the Common Kestrel, showed similar preferences for small rodents. The main food for both species is *M. arvalis*. Lack of variety of preferences for other species of small rodents indicates the existence of a common mechanism to choose prey for both species. Predominance of *M. arvalis* in the diet is due to the additive effect of the size of the predator and the number of prey. The size of *M. arvalis* is in the optimal range of prey size for both the Long-eared Owl and the Common Kestrel. Also, this scheme of prey selection is probably associated with several characteristics, such as daily and seasonal activity, mobility, spatial distribution, and most importantly, the colonial lifestyle of *M. arvalis*. The organization of their populations is based on a system of colonies (Romanowski 1988). The size of the colonies can range from a few to a dozen or more individuals. Probably, this feature of distribution of *M. arvalis* has led to the fact that many birds of prey specialize in hunting this species. It should be noted that this species is also one of the best adapted small rodents to live in highly transformed agricultural lands with frequent plowing. This feature allows *M. arvalis* to dominate by the number in small rodent communities in most of its range.

Conclusions

It has been found that within the urban ecosystem of Lviv, the Long-eared Owl and the Common Kestrel are typical small mammal specialist.

We found that the main food object is *M. arvalis* in both species. The lack of preferences in diet to other species of small rodents indicates the existence of a common mechanism for prey choice for both species. We assume that the size of *M. arvalis* is in the optimal range of prey size. We consider that the principle of prey choice in the studied bird species is associated with several characteristics of *M. arvalis*, such as daily and seasonal activity, mobility, spatial distribution, and most importantly, its colonial way of life and that this rodent species was the most abundant and thus, the most available prey. These biological features of *M. arvalis* encourage most birds of prey to specialize in hunting this species of rodent.

Unlike the Long-eared Owl, the diet of the Common Kestrel is more variable due to the consumption of different species of insects (families Gryllotalpidae, Tettigoniidae, Carabidae and Scarabaeidae) - 4/1, reptiles - 1/0 and birds - 7/5. This result suggested that dietary plasticity of the Common Kestrel facilitate successful adaptation to the urban landscape.

It has been found that small mammals comprise 98.4% in number and biomass of the diet of Long-eared Owls. Thus, the Long-eared Owl within Lviv territory is a typically theriophage with a slight manifestation of entomophagy, in contrast to the polyphagous Common Kestrel, which acts as a typical theriophage with elements of herpeto-, entomo- and ornithophagy. In summary, the Long-eared Owl is more strictly specialized in feeding on murine rodents that reduces trophic competition between the two species of predators in the urban ecosystem and coexists freely in the same types of habitats.

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Diet of the Red-footed Falcon *(Falco vespertinus)* in Cyprus during autumn migration

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Abstract The diet of the Red-footed Falcon *(Falco vespertinus)* was studied at Akrotiri Peninsula, Cyprus, in October 2008, during the autumn migration. Based on 180 pellets collected that represented 3,066 prey items, the diet consisted exclusively of invertebrates, nearly all preys were insects. Winged ants (Hymenoptera, Formicidae) formed 94% of the diet by number of specimens and 76% of biomass. Beetles (Coleoptera), mainly Carabidae and Scarabaeidae, made up 5% of the prey numbers but 22.5% of biomass. The other preys were made up by small numbers of earwigs (Dermaptera), true bugs (Hemiptera) and snails (Gastropoda).

Keywords: Akrotiri, ants, invertebrates, pellets, stopover

Összefoglalás A kék vércse *(Falco vespertinus)* táplálék-összetételét tanulmányozták 2008 októberében, az őszi vonulás idején a ciprusi Akrotiri-félszigeten. Az összegyűjtött 180 köpet 3066 zsákmányállat maradványait tartalmazta, ami kizárólag gerinctelenekből, szinte csak rovarokból állt. A zsákmány egyedszáma alapján a táplálék-összetétel 94%-át hangyák alkották (Hymenoptera, Formicidae), amik a biomassza 76%-át képezték. A bogarak (Coleoptera) közül főként a futóbogárfélék (Carabidae) és a ganéjtúrófélék (Scarabaeidae) a zsákmány 5%-át, a biomassza 22,5%-át tették ki. A zsákmány fennmaradó részét kis számban fülbemászó (Dermaptera), félfedelesszárnyú (Hemiptera) és csiga (Gastropoda) fajok egyedei képezték.

Kulcsszavak: Akrotiri, gerinctelenek, hangyák, köpetek, pihenőhely

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Introduction

The Red-footed Falcon *(Falco vespertinus)* is a small, gregarious, migratory falcon breeding in Eastern Europe, East to Central Asia and wintering in Southern Africa. It inhabits open lowland area, particularly steppes and farmland and breeds in abandoned nests of corvids (Cramp 1987). It is a species of global conservation concern, classified as near-threatened by IUCN, with a global population of 300,000–800,000 individuals (Ferguson-Lees & Christie 2001), including 30,000–63,000 pairs in Europe (Keller *et al.* 2019).

Its diet has been studied mainly during the breeding season (e.g. Purger 1998, Szövényi 2015, Tulis *et al.* 2017), while there are no published studies of its diet during the species long distance trans-Saharan migration and during its stay in the winter quarters. In this study, data are presented on the diet of the species in Cyprus, during autumn migration.

Cyprus is an important stopover site of the species, especially in autumn when there is usually a large passage, peaking from late September to mid-October (Kassinis & Charalambidou 2020). Spring passage is very small in numbers compared to autumn migration. The study was based on pellets collected during field studies by the Game and Fauna Service personnel.

Study area and methods

The study area is located at Akrotiri peninsula, in the southernmost part of the island of Cyprus *(Figure 1)*. This site is an internationally important stopover for the Red-footed Falcon, since hundreds to thousands birds are recorded each year (Zalles & Bildstein 2000, Hellicar *et al.* 2014). During the years 2009–2019, systematic autumn counts ranged from 106–1,331 birds, with a peak at early October (Kassinis & Charalambidou 2020) while the species is monitored annually during autumn migration. Red-footed Falcons stay and hunt in the peninsula in the extensive citrus plantations, open irrigated fields sown with clover and fallow areas in the vicinity of the wetlands. They are observed hunting from their roosting places, catching prey in flight, but also hunting and catching prey on open fields. Parts of the peninsula (especially citrus plantations and arable fields) are under considerable development pressures, with hundreds of hectares of agricultural land being lost.

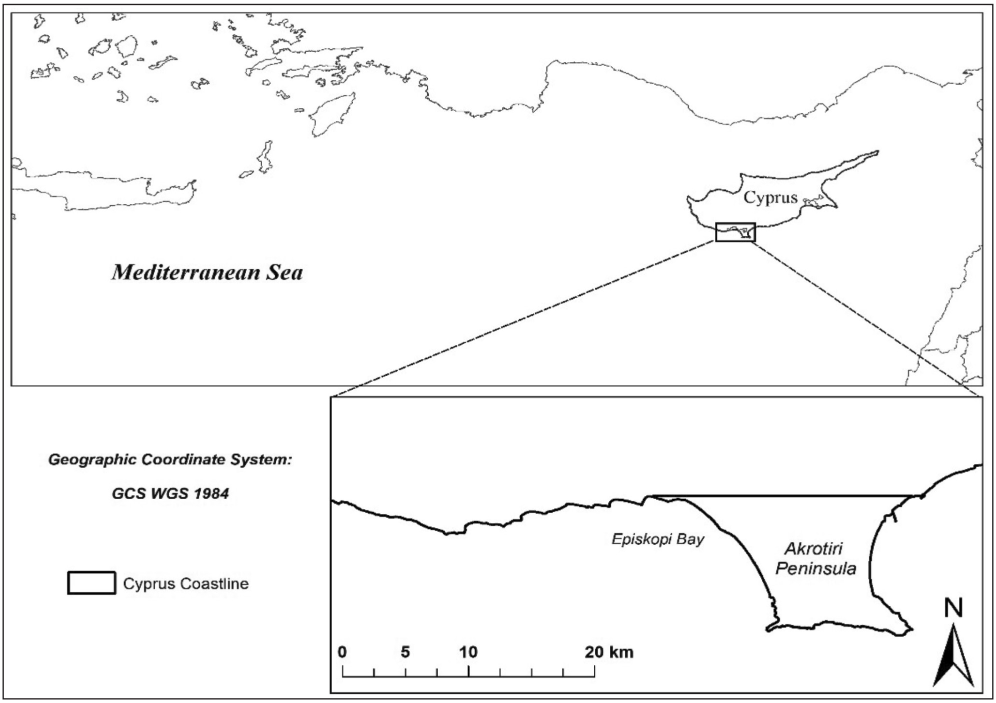

Figure 1. Cyprus map with Akrotiri Peninsula
1. ábra Ciprus térképe az Akrotiri-félszigettel

Pellets were collected in October 2008 in citrus plantations under gregarious falcon nighttime roosts and under power lines crossing orchards and fields used by large groups of falcons during hunting. Only fresh and entire pellets were collected and were placed in plastic bags and sealed.

It is unlikely that any of the pellets collected belonged to other species. The pellet content was analyzed and the insects were identified to the family level with the help of the insect guide (Chinery 1993); no attempt was made to identify them to a lower level.

Results

In total, 180 pellets were analyzed, from which 3,066 prey items were identified. The diet consisted exclusively of invertebrates, nearly all prey were insects *(Table 1)*.

Winged ants (Hymenoptera, Formicidae) made up 94% of the prey item abundance and 76% of the biomass. Beetles (Coleoptera) were also important (5% abundance, but 22.5%

Table 1. Diet of the Red-footed Falcon at Akrotiri Peninsula, Cyprus
1. táblázat A kék vércse táplálék-összetétele a ciprusi Akrotiri-félszigeten

Prey categories	Number of prey items	Items (%)	Biomass (%)
MOLLUSCA	3	0.1	0.4
Gastropoda indet.	3	0.1	0.4
INSECTA	3,063	99.9	99.7
Dermaptera	16	0.5	0.2
Forficulidae	16	0.5	0.2
Hemiptera	1	<0.1	0.1
Lygaeidae	1	<0.1	0.1
Coleoptera	155	5.0	22.5
Carabidae	95	3.1	12.5
Staphylinidae	15	0.5	2.0
Alleculidae	6	0.2	0.8
Tenebrionidae	3	0.1	0.6
Elateridae	1	<0.1	0.1
Buprestidae	1	<0.1	0.3
Scarabaeidae	18	0.6	4.8
Curculionidae	10	0.3	1.3
Cerambycidae	2	<0.1	1.1
Coleoptera indet.	4	0.1	<0.1
Hymenoptera	2,891	94.3	76.3
Formicidae	2,891	94.3	76.3
Total	3,066	–	–

biomass), mainly Carabidae and Scarabaeidae, with some Staphylinidae, Curculionidae and others. The other preys were only a few earwigs (Dermaptera), true bugs (Hemiptera) and snails (Gastropoda), which biomass ranged between 0.01–2.00 g, mean 0.12 g.

Discussion

To our knowledge, this is one of the first studies on the diet of the Red-footed Falcon in a migration area, beside Golawski *et al.* (2017) from Poland. It is notable that its diet consisted exclusively of invertebrates, particularly winged ants. During breeding season the Red-footed Falcon was feeding mainly on larger insects (Orthoptera, Coleoptera and Odonata) and small vertebrates as well (mainly amphibians and small mammals). This is probably because larger prey is more economical to carry in the nests (Purger 1998, Palatitz *et al.* 2015, Szövényi 2015). The sample from Poland (Golawski *et al.* 2017) consisted mainly of larger insects (Orthoptera and Coleoptera) and only 3.2% ants; there were also some small vertebrates (rodents). Thus, this sample was more similar to those in the breeding season than that of our study. Smaller but abundant prey can be consumed efficiently during migration, provided that is abundant enough, as it can be eaten very quickly. It can thus be assumed that winged ants were particularly abundant in the study area during the passage of the Red-footed Falcons, otherwise such small prey would not be so prevalent in the diet.

There are several studies of other small falcons that are largely insectivorous, at least outside the breeding season. The diet of the Amur Falcon *(Falco amurensis)* has been studied both in the breeding range (Mongolia) and in the wintering area (South Africa) (Schäfer 2003, Alexander & Symes 2016). This species feeds mainly on arthropods (Coleoptera, Orthoptera, Isoptera, Solifugae and Hymenoptera) in the winter quarters, but takes more vertebrates when breeding.

The diet of the Lesser Kestrel *(Falco naumanni)* has been studied in Spain, Israel and Greece (Pérez-Granados 2010, Kopij & Liven-Schulman 2012, Makri *et al*. 2016). In Spain and Israel, the diet was studied during the breeding season, and consisted mainly of large insects (mainly Orthoptera and Coleoptera), although in the former area small mammals made up about 50% of the diet by biomass. In Greece, pellets were collected before, during and after the breeding season. In the pre-breeding period, the main diet, by number, consisted of 43% Coleoptera, 32% Hymenoptera (Formicidae) and 10% Orthoptera. During the breeding season there were 69% Orthoptera, 25% Coleoptera and 4% Hymenoptera, while after breeding there were 50% Orthoptera, 32% Coleoptera and 11% Hymenoptera. Thus, during breeding the Lesser Kestrels took mainly larger insects, while winged ants were taken at other seasons.

In an extensive study in Greece, Eleonora's Falcons *(Falco eleonorae)* were feeding mainly on insects before breeding, but switched to birds during the breeding season. The main insects taken were 45% cicadas (Homoptera), 35% winged ants (Hymenoptera) and 16% Coleoptera (Xirouchakis *et al.* 2019). Thus, it appears that several small falcons may feed mainly on large insects and vertebrates during the breeding season (in particular, when have to carry food to the nest), but, outside breeding season may take a variety of small prey, such as arthropods. In many such cases, even small but abundant social insects (ants and termites) can be very profitable and important prey.

The results of this study on the diet of the Red-footed Falcon should be considered as preliminary, since, only one sample was collected during one migration season at Akrotiri Peninsula (Cyprus). More sampling throughout the migration period in other years might reveal a more diverse diet, affected by climatic or other conditions.

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Breeding biology of the Woodcock (*Scolopax rusticola* L.) in the Carpathian Basin

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Abstract Based on 356 observations of Woodcock nestings published in the Hungarian hunting and ornithological literature between 1846 and 2019, which also includes published and unpublished personal observations, it can be stated that the nesting dates of Woodcock in Hungary are scattered over a large interval. 47.3% of all nestings registered with exact dates (n=93) happen in April. The second peak of breeding in June does not stand out significantly. Based on the data of the clutches (n=65) reported with known number of eggs, as well as the clutches (n=14) – probably with full number of eggs – found in the Hungarian egg collections, the average number of eggs per clutch was 3.8. Based on the observational data of the Woodcock families (n=36) observed during the study period, the number of chicks per hen was 3.6, of which the hens were able to raise an average of 2.8 chicks up to a flying age.

Keywords: Woodcock, *Scolopax rusticola* L., breeding biology, nesting, raising of chicks, habitat, number of chicks, breeding losses

Összefoglalás A magyar vadászati és ornitológiai szakirodalomban az 1846–2019 között közölt és nem publikált személyes közlések erdei szalonka fészkelésre vonatkozó, 356 megfigyelési adata alapján megállapítható, hogy az erdei szalonkák magyarországi fészkelési időpontjai nagy intervallumon belül szóródnak. Az összes pontos dátummal regisztrált fészkelés (n=93) 47,3%-a április hónapra esik. A második, júniusi költési csúcs nem rajzolódik ki markánsan. Az ismert tojásszámmal közölt fészekaljak (n=65) adatai, továbbá a magyarországi tojásgyűjteményekben lévő – valószínűsíthetően teljes tojásszámú – fészekaljak (n=14) alapján az átlagos fészekaljankénti tojásszám 3,8 volt. A vizsgált időszakban megfigyelt szalonkacsaládok (n=36) adatai alapján az egy tojóra jutó csibék száma 3,6 példány volt, amiből a tojók átlagosan 2,8 csibét tudtak felnevelni röpképes korig.

Kulcsszavak: erdei szalonka, *Scolopax rusticola* L., költésbiológia, fészkelés, csibenevelés, habitat, csibeszám, költési veszteség

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Introduction

The European nesting population of the Woodcock (*Scolopax rusticola* L.) is estimated to have 6.89 to 8.71 million females. According to population estimation data, a significant proportion of the nesting population (84%) is located in Russia, representing around 6–7 million females (BirdLife International 2016). In Hungary, a larger number of specimens can typically be observed only during the spring (March–April) and autumn (September–October) migration. At the southern edge of their breeding area, the number of hens nesting sporadically is about 10–60 specimens per year (Hadarics & Zalai 2008).

In Hungary, only two comprehensive domestic studies have been published so far (Vönöczky Schenk 1944, Bende & László 2020) to summarize the knowledge related to the size of the nesting population and to the nesting areas, but no detailed publication analysing the breeding biology and nesting characteristics of the species has been prepared. In our study, we attempted to form a more complete picture of the breeding biology of the Woodcock by processing 174 years of literature data between 1846 and 2019.

Material and Method

The basis of our study was the observations (n=356) on the Hungarian Woodcock breeding known from the Hungarian hunting and ornithological literature, together with the unpublished personal observations, and the database compiled on the basis of clutches found in the Hungarian egg collections. During the processing, we determined the time distribution of nestings between March and August on a decade basis, based on the data of nests (n=93) reported with a known time of discovery. By processing the data of known nests (n=79) from Hungary, probably with full number of eggs, we analysed the distribution of clutches based on the number of eggs and the average number of eggs per hen. Based on the complete or partial mortality data of 38 nests of these known-sized clutches, we determined the distribution of the known factors causing nest losses. From the data on 98 Woodcock families and Woodcock chicks (n=239) published over the last 174 years, we determined the average number of flightless chicks (n=57) per hen, based on the reports (n=36) on the development and estimated age of the birds. The number of chicks raised by a single hen could be determined using the available information of observations of flying, immature birds (n = 56). We also determined the factors causing the death of Woodcock chicks (n=25). We compared the results of breeding biology from the synthesis of the collected data on the Carpathian Basin with the data in the international literature. We processed the basic data using Microsoft Excel 2016.

Results and Discussion

Nesting time

According to the observations on the island of Saaremaa in Estonia between 1886 and 1915, the breeding season occurred between 1 April and the end of July, breeding was irregularly long-continued, and second breeding of the species was rare (Steinfatt 1938). Based on a breeding biology study conducted in Whitwell (North Yorkshire, UK) from 1977 to 1981, the nesting period began as early as the second week of March (11 March), but the main breeding period started in April and typically lasted until the end of May. The frequency of nesting in late May to June depended on the extent of the summer drought. Woodcock nests could be found only during the rainy summer seasons. If the nest is destroyed, renesting is common after 10–14 days (Hirons 1982). According to the studies in Great Britain (n=218) from Hoodless (1994), the nesting period occurred from 8 March to 21 July. Examining each region, he demonstrated differences in the dates of laying the first eggs (Central and Southern England (14 April; n=86), Northern England (18 April; n=67), Scotland (25 April; n=65)). The dominant laying period nationwide was between 26 March and 25 April. Woodcocks nest in Central Europe later, typically from the second week of April until the end of July (Szabolcs 1971, Shorten 1974). Nesting dates from Russia (Kiev region – Charlemagne 1933, Novgorod region – Gementiev & Gladkov 1951) were recorded between 16 April and 15 July.

Based on the time difference – which is just enough for the first generation of Woodcocks to become independent – between normal nesting seasons in spring and nests found on a specific summer, and because of the different nesting sites, Ertl (1902) found that some of the Woodcocks breed up to twice a year. This finding was also confirmed by the observations made in July and early August, which is similar to the spring roding of the Woodcocks. The possibility of Woodcocks breeding twice a year was accepted by the Helsinki Hunting Congress in 1924 and the Stockholm Hunting Congress in 1930. According to Panka (1938), the Woodcock normally breeds only once, but if the first nest is destroyed, it might lay eggs again. Based on the observations of the mating Woodcocks in the pine forests along the Garam River (Hron, Slovakia) and in the mountains around Tiszolc (now Tisovec, Slovakia) in July and August during the evening and dawn roding and on the data on breeding hens found during this period, Lokcsánszky (1935) concluded that the second breeding of the Woodcock was possible. His conclusion was supported by the fact that he found two Woodcocks examined between 3 and 7 August with swollen, active genitals. Zsilinszky (1943) reported the possibility of the second breeding as a fact: *„The hen guides the chicks from the first breeding until mid-June, and then, when they become capable of flight, they fledge and scatter. This is when the second mating, in June, begins, which takes place just as in April. The rooster searches for the hen with the same raspy hissing as in early spring…"* Observations of summer rodings can be evidences of second breeding or even breeding, and the events of Woodcock mating in the summer can indeed support Woodcock nesting nearby (Anonymous 1902, Unger-Ullmann 1934, Farkas 1935, Zsilinszky 1943, Anonymous 1950, Horváth 1989, Fenyősi & Stix 1993). Lönnberg (1921), Witherby *et al.* (1941), Niethammer (1942), Zsilinszky (1943), Agárdi (1968) and Makatsch (1974) also suggested that two breeding attempts per year are possible, but so far this has not been credibly proven. Agárdi (1968) reported a clutch containing eggs found on July 2, 1966, however, the fact of the second breeding cannot be justified in this case either. In May 1967, Varga (1970) assumed post-breeding, based on the late dates of two feathered chicks reported to him, whilst he considered the clutch found on June 30, 1971, to be of first breeding despite the late date (Varga 1977). The latest hatching time of a clutch reported by Varga (1975) was July 20. In these cases, Varga (1975) maintains the possibility of a second breeding. So far, the latest known nesting data in the territory of the Kingdom of Hungary is August 19, 1902 – Liptóújvár Region (Gemer and Kis-Hont County, today Liptovský Hrádok, Slovakia) (Ertl 1902). Haraszthy (2019) classifies the clutches found in May and early June as renestings, while the nests at the end of June, July and August are certainly considered to be from second breeding. At the edge of the nesting area, it is difficult to take a clear position on

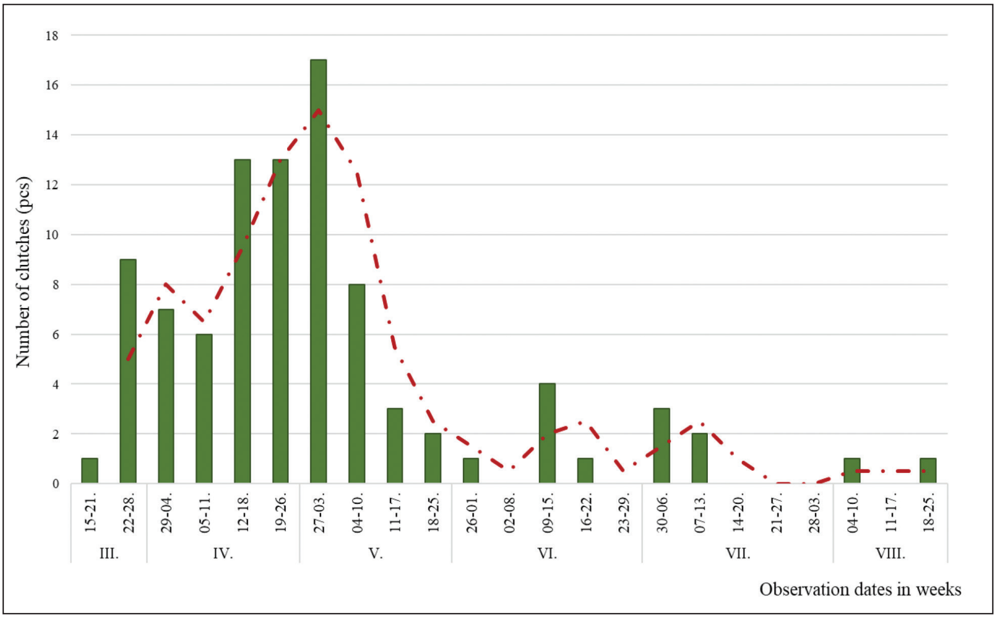

Figure 1. Distribution of dates of Woodcock (*Scolopax rusticola* L.) nests' discovery (n=93) between 1846–2019 during the breeding period

1. ábra Az 1846–2019 között megtalált erdei szalonka fészkek (n=93) időbeli eloszlása

second breeding, as there are very few breeding observations and we do not know of any proven data on second breeding.

Based on the time distribution of nestings (n=87) with exact dates observed in Hungary between 1846 and 2019, including the number of clutches with known collection times (n=6) in Hungarian egg collections, the main breeding period is between April and May *(Figure 1),* 86% of the observations come from this period (Lakatos 1886, Anonymous 1893, Teschler 1893, Ertl 1897, Gy. Takách 1901, Lintia 1907, Sugár 1916, Veress 1916, Preuszler 1917, Károlyi 1921, Mérey 1928, Dorner 1930, Réz 1930, Steiner 1930, Szurmay 1933, Kiskárpáti 1935, Boroviczény 1936, Say 1937, Berényi 1938, Csiba 1959, 1968, Varga 1966, 1977, 1979, 1980, Juhász 1970, Szabolcs 1971, Csaba 1974, Bársony 1985, Faragó 1987, Haraszthy & Viszló 2010, Fuisz *et al*. 2015a, 2015b, Pereszlényi *et al*. 2015, Rác 2015, Kozma & Vadász 2018). Observational data on summer renestings and possible second breedings are only 14% (Lovassy 1884, Orlovszky 1889, Ertl 1897, 1902, Agárdi 1968, Varga 1975, 1977, 1979).

Based on data from the Carpathian Basin, the distribution within the breeding period fits well with the results of studies in Germany (Steinfatt 1938), England (Morgan & Shorten 1974, Hirons 1982), and Great Britain (Hoodless 1994). According to these, the timing of Woodcock breeding is independent from specific geographical features, although its beginning differs based on British results. Given the hectic nature of renestings, the second breeding of the species in our area cannot be ruled out either, despite the fact that the second nesting peak in June is not clear. In case of a successful early first breeding, we consider a second breeding possible. Kalchreuter (1983) concluded that the number of clutches per year was likely to vary from year to year and from region to region.

The size of the clutch

The Woodcock lays eggs every 1–2 days (Cramp & Simmons 1983), sometimes every 3 days (Makatsch 1974). In the case of Woodcock nests studied in Great Britain (n=12), the average laying interval was 1.25 days, which means an average egg-laying period of 5 days in a clutch with four eggs (Hoodless & Coulson 1998). According to the observation of Román (2019 pers. comm. not published), the hen laid one egg every 2 days.

The size of the clutch can vary from 2 to 5 eggs; the clutches usually have 4 eggs (Makatsch 1974, Cramp & Simmons 1983, Glutz *et al*. 1986, Hoodless 1994). Regarding the size of renesting, Makatsch (1974) also gives 4 eggs as the most common clutch size. According to the British data from Hoodless and Coulson (1998), clutches (n=277) can be 2–5 eggs in size. 88.8% of the nests they examined contained 4 eggs, while 9.0% contained 3 eggs; the average number of eggs was 3.9. Based on his studies in England (n=330), Alexander (1946) gave an average of 3.8 eggs per nest, which is almost the same value (3.9) as the later study of Morgan and Shorten (1974) suggests. They found no difference between the average size of clutches (n=168) from different areas of Great Britain: Scotland (n=60) the average was 3.9; Northern England (n=64) the average was 3.8; Southern England (n=44); the average was 3.8. Based on a study by Hirons (1982) in England, the average clutch size was 3.9 eggs (n=20). Knefély (1987) found an average of 3.7 eggs per nest (n=77) in Germany.

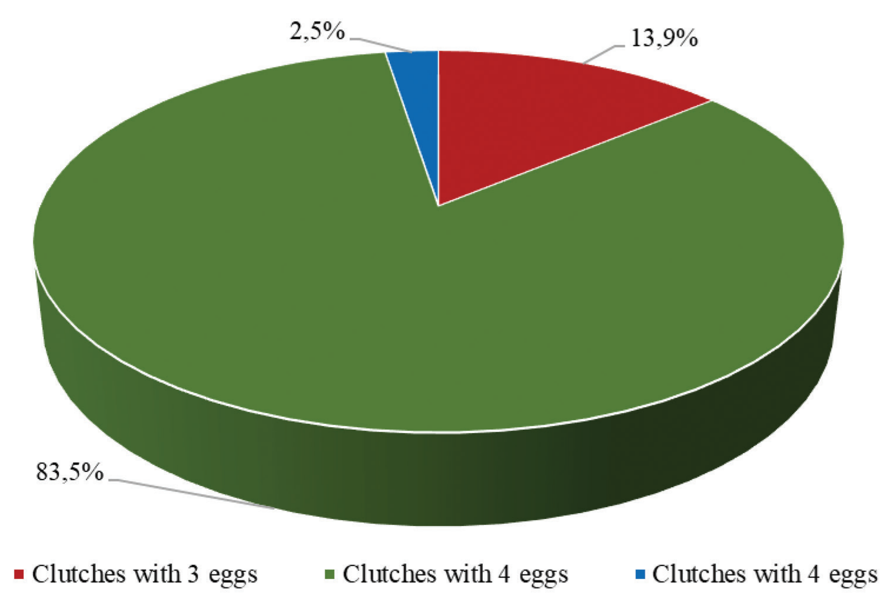

Figure 2. Distribution of Woodcock (*Scolopax rusticola* L.) clutches (n=79) based on the number of eggs between 1846–2019

2. ábra Az erdei szalonka 1846–2019 között megtalált fészekalj (n=79) méretek eloszlása

The data of clutches (n=65) found in Hungary with known number of eggs, as well as the nests (n=14) in the Hungarian egg collections – probably complete – include two 1-egg nests (Maltotai 1906, Réz 1935). Nests with three eggs (n=11) were found by (Széchényi 1879, Lovassy 1891, Mérey 1928, Kiskárpáti 1935, Vásárhelyi 1936, Agárdi 1939, 1968, Faragó 1987, Haraszthy & Viszló 2010), four eggs (n=66) (Lovassy 1883, Chernel 1885, Orlovszky 1889, Gy. Takách 1901, Ertl 1902, Anonymous 1907, Lintia 1907, Sugár 1916, Chernel 1918, Dorner 1930, Réz 1930, Szurmay 1933, Kiskárpáti 1935, Réz 1935, Anonymous 1936, Vásárhelyi 1936, Say 1937, Berényi 1938, Agárdi 1939, Csiba 1959, Varga 1966, 1968, 1977, 1979, 1980, Juhász 1970, Csaba 1974, Faragó 1987, Haraszthy & Viszló 2010, Haraszthy 2012, 2015a, 2015c, Fuisz *et al*. 2015a, 2015b, Rác 2015, Solti *et al*. 2015, Kozma & Vadász 2018, Pukánszki 2018) and five eggs (n=2) (Veress 1916, Réz 1928) *(Figure 2)*. The average clutch size was 3.8 eggs (n=79), which fits well with the European data known from the literature. There is no geographical difference in the size of the clutches, neither in Europe, nor in Hungary.

Breeding

According to studies by Hirons (1982) in England, the fertility of the Woodcock eggs is 96.4%. Similarly, McKelvie (in Asbót *et al*. 1987) found this to be 90% in his studies. We know about only three reports on rotten eggs from Hungary (Bóta 1943 Varga 1966, 1968), so the fertility value in Hungary cannot be determined, but we assume that this ratio is similar to international levels. The hen begins to incubate after the last egg laid, so the hatching of the chicks is synchronized. According to observations in England, the incubation period was 21 days (McKelvie in Asbót *et al*. 1987), while in Great Britain, based on more detailed observation data, the average incubation period was 21.9 days (n=15, min. 17, max. 24) (Hoodless & Coulson 1998), which corresponds to the data from Makatsch (1974), Glutz *et al*. (1986) and Cramp and Simmons (1983). The breeding time observed in Hungary was 23 days (Román 2019 pers. comm. not published).

Breeding losses

During the studies conducted by Hirons (1982) in Whitwell, North Yorkshire, 47% of nests (n=19) were destroyed; in two cases, due to predation by Red Foxes *(Vulpes vulpes)* when the hen was also killed. During a study conducted in Great Britain, 933 eggs in 277 nests were examined, 74.1% of which hatched (Hoodless 1994, Hoodless & Coulson 1994). During the studies of Morgan and Shorten (1974), 288 of the 453 eggs hatched (63.8%); the main factor causing the loss was nest predation. In the study of Hoodless and Coulson (1994), 44 hens left the nests during the breeding period, of which 31 were abandoned due to human disturbance (scaring away the hen from the nest), in four cases due to forestry activities, three times due to extreme weather, and in six cases the Woodcocks left their eggs for unknown reasons. In the latter cases, it is probable that the feeding hen fell prey and therefore did not return to the nest. 55 clutches were destroyed by various predators, in four cases not only the clutches but also the breeding hens were killed. The most common winged predators of the eggs are the Eurasian Jay *(Garrulus glandarius)* and the Carrion Crow *(Corvus corone corone)*. Among the mammals, the nest predation of the Wood Mouse *(Apodemus sylvaticus)*, the European Hedgehog *(Erinaceus europaeus)*, the Stoat *(Mustela erminea)*, the Red Fox, and the Wild Boar *(Sus scrofa)* is known (Nyenhuis 1991, 2007, Isaksson *et al*. 2007, Pedersen *et al*. 2009).

Based on nesting data from Hungary, we have information on the complete or partial destruction of 38 of the 79 clutches with known size. Of the 307 eggs, 100 perished. One report is known when the hen died along with her clutch (Varga 1977). Details of nest destruction due to the winter weather during the nesting period are reported in one case. (Berényi 1938). Based on data on nests destroyed by predation, three nests were destroyed by Red Squirrel *(Sciurus vulgaris)* (Juhász 1970), while one nest was destroyed by Hedgehogs (Varga 1980). In one case, Varga (1968) presumed predation by a Red Fox or Wildcat *(Felis silvestris)*. Numerous data are known on the nest-destroying effects of human activity. In one case, children destroyed a clutch (Kiskárpáti 1935), and in two cases the clutches fell victim to forestry work (Csete 1936, Faragó 1987). The clutches were placed in egg collections in 17 cases (n=57 eggs) (Lovassy 1891, Haraszthy & Viszló 2010, Haraszthy 2012, 2015a, 2015b, 2015c, Fuisz *et al*. 2015a, 2015b, Haraszthy *et al.* 2015, Rác 2015, Solti *et al*. 2015). The egg collection has been ended, so this loss is no longer a factor. In three cases, the hen left the nest permanently, presumably due to other human disturbance (Dorner 1930, Varga 1979, Haraszthy 2019), and three more nests were destroyed for unknown reasons (Varga 1980, Román 2019 pers. comm. not reported).

Raising of chicks, the number of chicks per hen

According to observations from Russia, chicks weight 17–20 g hatch in 5–6 hours (Gementiev & Gladkov 1951). Only the hen takes care of the chicks. After drying, hatched chicks leave the nest under the guidance of their mother. On the first day, they are only 20–30 meters away from the nest (Varga 1977). Chicks develop rapidly, being able to fly after 20 days of age (Hirons 1982), while from day 35–42, they become completely independent (Hirons 1982, Cramp & Simmons 1983). Hens usually guide their chicks alone, but a publication is also known in which two Woodcock families wandering together are reported (Deák 1885, Faragó 1987).

According to a study in Great Britain (McCabe & Brackbill 1974), the survival rate in the first month after hatching is 78%. In England, the number of flying chicks per hen was 2.3 (n=20) (Hirons 1982). During the study of clutches in Germany (n=77), an average of 2.9 chicks per nest (n=49) were registered (Knefély 1987).

From the data on 98 Woodcock families and Woodcock chicks published in Hungary over the last 174 years, the number of chicks was known in 76 cases, which means the data of a total of 239 chicks. Data on the development and estimated age of the birds were reported in 51 cases, of which the number of chicks was given in 36 cases. Of the reports of more downy or more advanced but still flightless birds (n=29), in the cases published with a known number of chicks (n=16), observational data are published for a total of 57 chicks (Chernel 1885, Anonymous 1898, Anonymous 1910, Polgár 1922, Janisch 1924, Breuer

1929, Réz 1928, 1930, Várady 1932, Kiskárpáti 1935, Réz 1935, Bóta 1943, Hoffmann 1950, Varga 1966, 1968, 1970, Faragó 1987). Based on the above, the hens guided an average of 3.6 chicks. Based on the reports of domestic observations of young birds (n=20) that have already fledged (Széchenyi 1871, Anonymous 1889, Anonymous 1891, Janisch 1924, Réz 1930, Kozarits 1935, Varga 1966, 1968, 1970, Faragó 1987, Kuslits 2019 pers. comm. not published, Mogyorósi & Kuslits 2019 pers. comm. not published), the data of 56 specimens are known; based on this, the average number of chicks per hen was 2.8, which means a survival rate of 78.7%. This value fits well with the data on the number of chicks per hen (2.3–2.9 chicks/hen) reported in the international literature (Hirons 1982, Knefély 1987). We can conclude that the nesting success at the edge of the nesting area is similar to that in the central area of the nesting distribution.

Summary

According to international literature (Gementiev & Gladkov 1951, Morgan & Shorten 1974, Hirons 1982, Hoodless 1994,), the main breeding season of Woodcock is in April-May, but breeding in March is not uncommon in Great Britain (Hirons 1982, Hoodless 1994). According to our research, the main breeding period in Hungary is also in April-May; we know more than two-thirds of the nestings from this period. Based on the international literature data and our own results, it is not possible to determine a clear trend-like time shift in the nesting period although the climatic conditions of this widespread breeding distribution, and presumably the altitude as well, affect the timing of the beginning of nesting, e.g. Hoodless (1994). In connection with second breeding, neither the international (Lönnberg 1921, Witherby *et al.* 1941, Niethammer 1942, Makatsch 1974) nor the Hungarian (Anonymous 1902, Ertl 1902, Unger-Ullmann 1934, Farkas 1935, Panka 1938, Zsilinszky 1943, Anonymous 1950, Agárdi 1968, Varga 1970, Varga 1975, Horváth 1989, Fenyősi & Stix 1993, Haraszthy 2019) literature is uniform. Knowing the nesting data from Hungary, in the case of successful early first breeding, we consider the second breeding of the species possible in Hungary as well, considering the nesting data from July and early August. This may not be significant, as the second summer nesting peak does not stand out clearly. Based on the data on nest mortality from Hungary, compared to the British data (32.6%) from Hoodless and Coulson (1998), the rate of loss caused by human factors is very high, which can be attributed to the data of egg collections, which is now outdated. Furthermore, the share of predation (50%) is lower than in Great Britain (57.9%). Few data on natural nest predators are reported in the Hungarian literature, but based on international data, it can be assumed that the loss attributable to this is greater than the domestic data, so the actual rate of human destruction determined by the results of this study might be lower. Comparing the data of scattered nesting in Hungary with the data of the countries with a significant nesting population published in the international literature, it can be stated that there is no significant difference in terms of clutch sizes (3.9 eggs/nest) and the number of chicks raised per hen (2.8 specimens/hen), which refers to the uniform breeding biology of Woodcocks throughout Europe.

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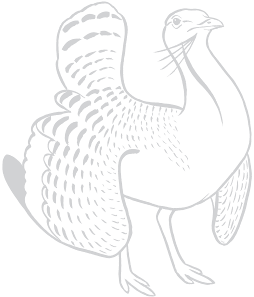

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The possible occurrence of cranial asymmetry in three harrier (Accipitridae: *Circus*) species

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Abstract The harriers (Accipitridae: *Circus*) represent a unique group of raptorial birds due to their hunting behaviour and their facial ruff and prominent facial disc. During previous studies it was suggested that harrier species may have other convergent features shared with owls like asymmetric or enlarged ear openings related to sensitive hearing capabilities. In this study, cranial asymmetry was done using SAGE (Symmetry and Asymmetry of Geometric Data) software. 32 skulls of 3 species (Western Marsh Harrier *(Circus aeruginosus*) n=8, Montagu's Harrier *(Circus pygargus)* n=10, Hen Harrier *(Circus cyaneus)* n=14) were photographed, digitized and assigned with 2D landmarks with TpsDig software. The variables were analysed based on Generalized Procrustes analysis. The morphometric data showed cranial asymmetry of harriers. This asymmetry should rather be explained by foraging strategies as the results are corresponding to the exceptionally good hearing of these species among diurnal raptors.

Keywords: cranial morphology, morphometrics, anatomy, skull, shape, convergent evolution, harrier, auditory system

Összefoglalás A rétihéják (Accipitridae: *Circus*) egyedi képviselői a ragadozó madaraknak, köszönhetően sajátos vadászati technikájuknak és megjelenésüknek, a tollak által alkotott gallérral és arcfátyollal. A korábbi kutatások során felvetődött, hogy utóbbiakon kívül más konvergens tulajdonságokon is osztozhatnak a baglyokkal, mint amilyen az aszimmetrikus vagy megnagyobbodott fülnyílás, amely érzékeny hallásukra utal. Jelen tanulmányban a koponya aszimmetria vizsgálatát a SAGE (Symmetry and Asymmetry of Geometric Data) szoftver segítségével végeztük. Összesen 3 faj 32 koponyájának (barna rétihéja – *Circus aeruginosus*, n=8, hamvas rétihéja – *Circus pygargus,* n=10, kékes rétihéja – *Circus cyaneus,* n=14) fényképét digitalizálva, kétdimenziós landmarkokkal láttuk el azokat a TpsDig programban. A változókat Prokrusztész analízis segítségével vizsgáltuk, ahol a morfometriai adatok aszimmetriát mutattak a rétihéja koponyákon. Ez az aszimmetria a táplálkozásmóddal és viselkedéssel köthető össze és megerősíti azt a megállapítást, miszerint nappali ragadozókhoz mérten ezek a madarak kifinomult hallással rendelkeznek.

Kulcsszavak: koponyasajátosságok, morfometria, anatómia, koponya, alak, konvergens evolúció, rétihéja, táplálékpreferencia, auditív érzékelés

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Introduction

The harriers (Accipitridae: *Circus*) represent a unique group of raptorial birds due to their particular hunting behaviour (Redpath 1992), low, quartering flight, exceptionally light wing loading, their mating pattern of polygyny. In their external appearance, harriers are one of the most easily recognisable Accipitrinae raptors due to their external features such as facial ruff and prominent facial disc (Simmons 2000). Harriers have traditionally been placed within the subfamily Circinae (Peters 1931), but recent molecular studies have revealed that harriers are more closely related to *Accipiter* (Nagy & Tökölyi 2014, Oatley *et al*. 2015). The feeding strategies are highly diverse and the morphological adaptations for feeding are a notable feature of avian evolution (Zusi 1993, Zweers *et al.* 1994). As in many other avian groups, food supply is one of the main factors influencing the ecology of raptors. Population densities of raptors are often limited by food supply (Newton 1980, Franklin *et al.* 2000), which also influences the number of specialist hunters being more likely to fluctuate annually when dependent on a fluctuating food source (Hamerstrom 1969, Korpimäki & Norrdahl 1991, Butet & Leroux 1993).

Previously, the adaptive significance of the anatomical and behavioural convergence between the harriers and some owl species was examined (Clark *et al.* 2020). Anatomically, both groups evolved a sound collecting facial ruff, a curved structure of skin and feathers surrounding the ears, and forage very close to the ground, harriers are very vocal birds while gliding over the hunting area (Rice 1980). The harriers circle an area several times listening and looking for prey, as they have exceptionally good hearing among diurnal raptors. It suggests that these species have a highly developed auditory system. The ears are covered by the feathers of the facial disc (Rice 1982). Some owl species also have a pronounced facial disc, guiding sounds into the ear openings. In owls, the beak is pointed downward, increasing the surface area over which the soundwaves are collected by the facial disc (Nishikawa 2002). Many owl species are remarkable for the bilateral asymmetry of the ears which attributes support a highly developed sense of directional hearing (Coles & Guppy 1988, Pecsics *et al.* 2018). However, the differences are represented by different tissues of the head (feathers, earflaps, ear holes, etc.), ear asymmetry basically caused by cranial structures only, due to the different positions and orientations of the *squamoso-occipital* wings. Ear morphology is different in structure and geometry between species (Norberg 1978). The symmetrical ears are representing a most basal form and cranial structure (Nishikawa 2002).

Bilateral symmetry is a subject of widespread interest, and structures with such symmetry are particularly considered when these consist of two mirror copies on opposite sides of the body (Klingenberg *et al.* 2002). Bilateral symmetry analysis focuses on identifying and measuring the location and extent of symmetry departures in structures, like in the context of matching symmetry, where the two mirror images are considered separated parts of the structure (Torcida *et al.* 2016).

Ear adaptations are a well-known feature of owl evolution. Also there are some documented size and shape asymmetries in birds (Norbeg 1978, Aparicio & Bonal 2002, Güntürkün *et al.* 2000, Parés-Casanova & Salas-Bosch 2020). It was suggested that harrier species may have asymmetric or enlarged ear openings for accurately pinpointing sound (Van Grouw 2012), but our knowledge is still limited regarding the degree and the direction of these skeletal asymmetries.

In this preliminary study, we investigated the cranial diversity among three harrier species. Our objective was to increase our knowledge in the relationship between skull shape and the possible asymmetric skeletal features. For this reason, we investigated shape asymmetries related to hearing capabilities.

Materials and Methods

Specimens

This study is based on 32 skulls of 3 species: Western Marsh Harrier *(Circus aeruginosus*) n=8, Montagu's Harrier *(Circus pygargus)* n=10, Hen Harrier *(Circus cyaneus)* n=14. All skulls are from adult specimens belonging to the collection of Eötvös Loránd University (Budapest, Hungary), the collection of the Hungarian Natural History Museum (Budapest, Hungary), Mátra Museum (Gyöngyös, Hungary) and the digital archives of Natural Sciences Museum of Barcelona (Barcelona, Spain). No bird has been killed to obtain its skull; all birds died either of natural causes, whether accidental death or whether death in captivity.

Landmarks and procedures

The variation of cranial morphology was analysed using landmark-based geometric morphometry. In this study, we tried to find landmarks for this analysis to cover the geometric form of the *regio oticalis*. Ideal landmarks are discrete and noticeable anatomical features that do not alter their topological positions, providing adequate coverage of the morphology (Zelditch *et al.* 2004). The landmarks were taken from high resolution (1200×1600 pixels) photos. We took 3 photographs from each specimen

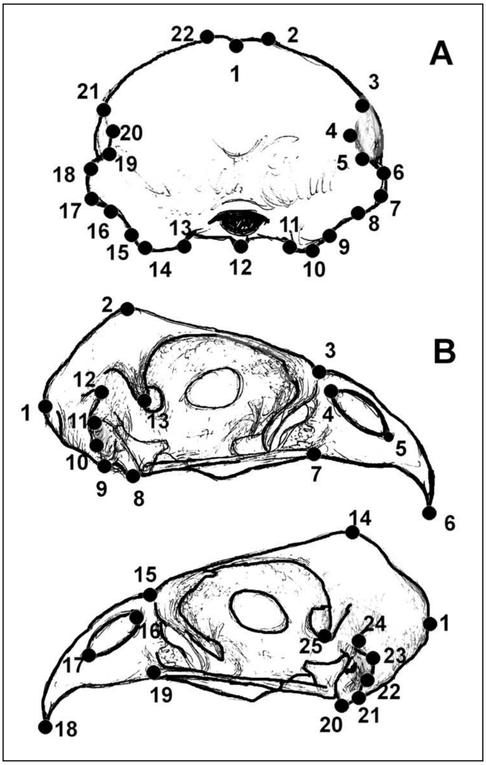

Figure 1. Position and number of landmarks. A: fixed landmarks in caudal view, B: fixed landmarks in lateral (left-right) view (numbers correspond to *Table 1*)

1. ábra A vizsgálatban használt landmarkok száma és pozíciója. A: fix landmarkok hátulnézetből, B: fix landmarkok oldalnézetből (bal-jobb) (a számok megnevezését lásd a *1. táblázatban*) (caudal, lateral – right and left). Images were standardised for the *foramen magnum occipitale* and the tip of the mandible. Testing for fluctuating asymmetry, three measurements were taken (replicates) per individual. For each specimen, 22 fixed landmarks were recorded in caudal view and 25 fixed landmarks in lateral view (right and left) *(Figure 1) (Table 1)*. The coordinates of the landmarks were digitised using TpsDig 2.16 software (Rohlf 2010) and were transformed using the Procrustes superimposition method. We used Mann-Whitney U two-tailed test for comparing the sides. To detect the components of variances

Table 1. Number and description of landmarks in caudal (A) and lateral (B) view (terminology according to Baumel 1993, Sun *et al.* 2018)

1. táblázat Az egyes landmarkok száma és leírása, hátulnézetben (A) és oldalnézetben (B) (terminológia Baumel 1993 és Sun *et al.* 2018 alapján)

A) Number of landmark	**Description of landmark**
1	mid section of the *neurocranium*
2 , 22	highest point of the *neurocranium*
3 , 21	top of curvature at the *superior* end of the *M. add. mandibular externus* scar
4 , 20	top of curvature at the *caudal* end of the *M. add. mandibular externus* scar
5 , 19	top of curvature at the *inferior* end of the *M. add. mandibular externus* scar
6 , 18	highest edge of the temporal wing
7 , 17	top of curvature at the *superior* end of the temporal wing
8 , 16	top of curvature at the *caudal* end of the temporal wing
9 , 15	top of curvature at *inferior* end of the temporal wing
10 , 14	lowest edge of the temporal wing
11 , 13	most inner edge of the temporal wing at the inferior end
12	lowest point of *condylus occipitalis*

B) Number of landmark	**Description of landmark**
1	*prominentia cerebellaris*
2 , 14	highest point of the *neurocranium*
3 , 15	mid-point of the *cranio-facial* hinge
4 , 16	top of curvature at the *caudal* end of the external nares
5 , 17	top of curvature at the *rostral* end of the external nares
6 , 18	tip of the beak
7 , 19	articulation point of jugal bar and *maxilla*
8 , 20	the *processus* of the *opisthotic*
9 , 21	lowest edge of the temporal wing
10 , 22	top of curvature at the *inferior* end of the temporal wing
11 , 23	top of curvature at the *superior* end of the temporal wing
12 , 24	highest edge of the temporal wing
13 , 25	*processus postorbitalis*

and deviations, Procrustes ANOVA was used (Klingenberg *et al.* 1998, Marquez 2006). Consensus configurations and relative warps were conducted. Variability in shape was assessed using the scores obtained for each individual on the first two relative warps. Cranial asymmetry was estimated using SAGE (Symmetry and Asymmetry of Geometric Data) software (Marquez 2006). We conducted principal component analyses (PCA) on these morphological variables in caudal view. The relative warps are corresponding to the principal components (PCs) and define the shape space in which individuals are replaced. We used PAST v.1.7 software (Hammer *et al*. 2001) for principal component analysis and to extract deformation grids. We only considered those PCs which are explaining >10% of the variance.

Results

Mann-Whitney U two-tailed test showed significant differences between the two sides of the skull regarding the temporal region (U=838.5; z=-8.22, P<0.001 at the significance level 0.01).

Procrustes ANOVAs revealed that directional asymmetry was greater than fluctuating asymmetry *(Table 2)* reflecting the coordinates in caudal and lateral view.

During the second analysis, we used 22 fixed landmarks recorded in caudal view. The first two PCs explained 38%, and 22% of the variance in shape. The first PC described the variation in shape, the second the relative orientation of the temporal wing which showed that *Circus* species differ considerably in their degree of asymmetry *(Figure 2)*. The Western Marsh Harrier showed less cranial asymmetry than the other two species, Montagu's Harrier was in intermediate position in the analysis and Hen Harrier showed the most asymmetric scores *(Figure 3)*.

Table 2. Results of ANOVA for the registered coordinates in caudal (above) and lateral view (bottom), with the effect of "side" (directional asymmetry) and "side*individual" effect (fluctuating asymmetry)

2. táblázat Az ANOVA eredményei a regisztrált koordináták tekintetében hátulnézetben (fent) és oldalnézetben (alul), az "oldal" (direkcionális aszimmetria) és az "oldal*egyed" (fluktuáló aszimmetria) hatásával

effect / hatás	**SS**	**MS**	**df**	**F**	**p**
individual / egyed	0.0566	0.0004	160	4.6948	0.001
side / oldal	0.0045	0.0002	20	2.9694	0.001
side*individual / oldal*egyed	0.0121	0.0001	160	16.7492	0.001
error / hiba	0.0032	0.0002	720		

effect / hatás	**SS**	**MS**	**df**	**F**	**p**
individual / egyed	0.0646	0.0004	184	4.7844	0.0001
side / oldal	0.0073	0.0003	23	4.346	0.0001
side*individual / oldal*egyed	0.0135	0.0001	184	93.4848	0.001
error / hiba	0.0006	0.0001	828		

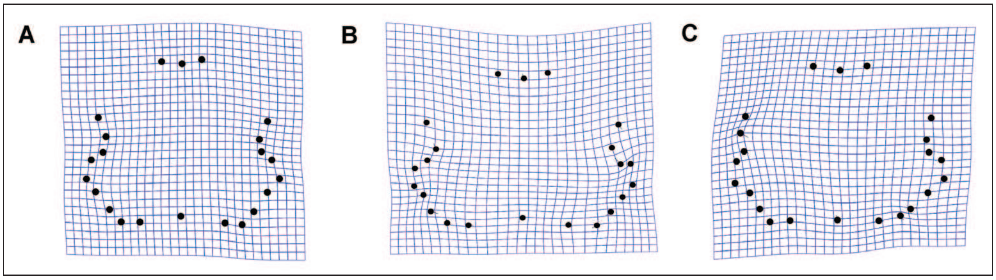

Figure 2. Various harrier species differ considerably in their degree of asymmetry (in caudal view). A: Western Marsh Harrier *(Circus aeruginosus)*, B: Montagu's Harrier *(Circus pygargus)*, C: Hen Harrier *(Circus cyaneus)*

2. ábra Az egyes rétihéja fajok különböznek az aszimmetria mértékében (hátulnézetben. A: barna rétihéja *(Circus aeruginosus)*, B: hamvas rétihéja *(Circus pygargus)*, C: kékes rétihéja *(Circus cyaneus)*

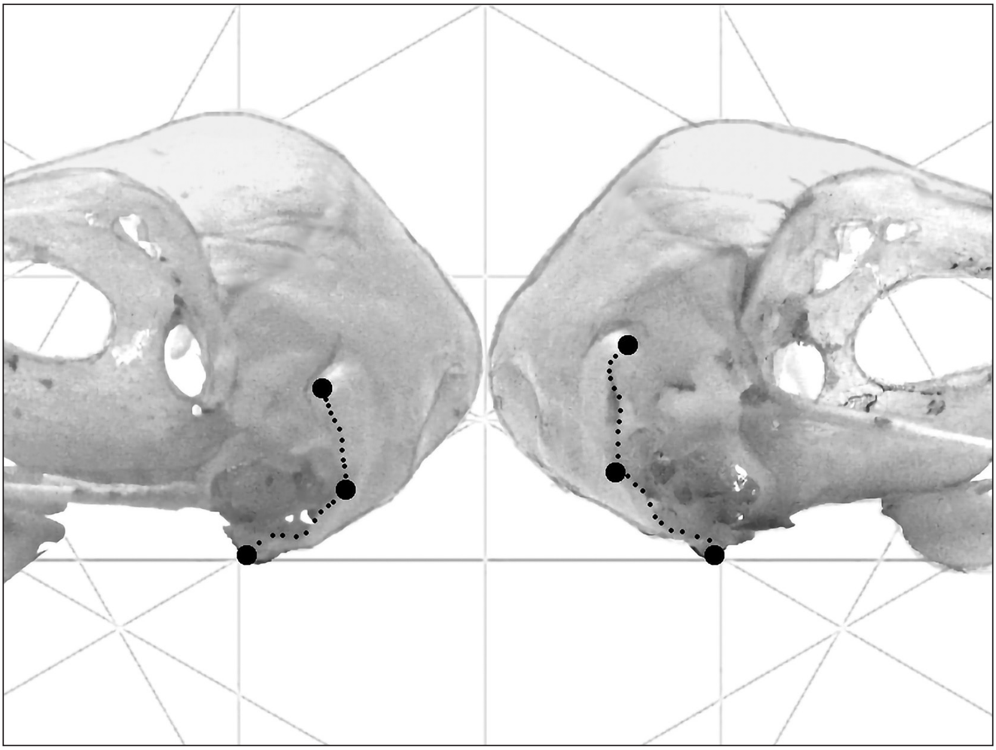

Figure 3. Differences in position and shape of left and right tympanic wings on the skull of a Hen Harrier *(Circus cyaneus)* specimen

3. ábra A kékes rétihéja *(Circus cyaneus)* egy példányának koponyáján lévő különbségek a bal és jobb oldali halántékcsont *tympanicus* nyúlványainak helyzetében és alakjában

Discussion

We found that the influence of directional asymmetry was greater than fluctuating asymmetry which suggests that these asymmetrical features probably evolved to support directional hearing and sound localization. In lateral and caudal view, there are differences in the size and orientation of the temporal wing between the species. However, the anatomical similarities between harriers can be explained by their slightly different foraging methods and hunting behaviour.

Comparisons between sympatric raptor species with similar ecological needs and preferences but different body size and social behaviour are helpful in assessing the influence of energy needs or dominance on foraging strategies and food partitioning (Fedriani *et al.* 2000, Buij *et al.* 2011). The Montagu's Harrier and the Hen Harrier are breeding and foraging sympatrically in many areas. The diet of these species is very similar (Millon *et al.* 2002). The species differ in size, Hen Harrier being larger and also there are differences in their breeding system (Cramp 1980). Food partitioning by size between species that differ in food requirements is expected and has been observed in other species too (Gerstell & Bednarz 1999). Accordingly, within the large spectrum of prey types indicated that Hen Harriers preyed more frequently on larger prey and Montagu's Harriers on smaller prey (including more insects). This kind of segregation was observed in the main prey (small lagomorphs and rodents), and in the sizes of the most important alternative prey (Garcia & Arroyo 2002, Arroyo & Garcia 2006, Arroyo 2008).

The competition between Western Marsh and Hen Harriers for hunting space in the same area was also observed, i.e. Western Marsh Harriers hunted mainly over the marsh (Buij 2012, Tornberg & Haapala 2013) resulting in niche separation between the two species. Western Marsh Harrier has proportionately shorter wings and tail, its flight is slower and less manoeuvrable compared to Hen Harrier. Western Marsh Harrier has longer tarsi which should be an adaptation to reach deep into tall marsh vegetation preferred to hunt, maybe because this gave it more opportunity for surprise during hunting (Clarke *et al.* 1993, Cardador *et al.* 2012).

Differences in foraging efficiency between generalist and specialist species could be explained by neural limitations. This means that generalists need learning to be able to narrow their resource choices (Bernays *et al.* 2004). Specialization may be also associated with morphological or behavioural adaptations to handle certain resources. Harriers are diurnal raptors but evolved a parabolic collar of feathers surrounding the eyes, suggesting that hearing is enhanced to locate small mammal prey hiding in dense vegetation (Rice 1982, Redpath 1992, Simmons 2000). The facial disc is more pronounced in those harrier species which are feeding on mainly small rodent prey like the Pallid Harrier *(Circus macrourus)* (Buij 2012). The facial disc encircling the ears and meeting below the beak, in contrast, the facial disc of the Montagu's Harrier is confined to an arc just behind the ear openings, suggesting its hearing capacities might be less well developed than that of the rodent specialist species (Clarke *et al.* 2008, Terraube *et al.* 2011). This is also in accordance with our results. The Western Marsh Harrier is a great opportunist with lack of specialization (which means very wide range of prey, varying with local availability) showed less asymmetrical features. The Montagu's Harrier is feeding on small ground birds, small mammals, reptiles and large insects (Thiollay 1994) but the Hen Harrier (which preys on mostly small rodents, like voles, mice, cotton rats, ground squirrels) (Garcia & Arroyo 2004) showed greater asymmetries in temporal region than the other two species. It suggests that feeding mainly on small rodents requires more sensitive auditory capabilities to detect the movement of the prey item. It is also possible that the relative size of the facial disc is in relationship with asymmetrical cranial structures, which also connected with hearing and auditory capabilities in owls (Norberg 2002). In the case of Hen Harrier some kind of nocturnal behaviour (Russell 1991) may have also effect on this feature.

Our results show relationships between cranial asymmetry and hunting behaviour but also highlight the morphological complexity and diversity of raptor skulls. Future studies should rather examine the possible interspecific and intersexual differences that may have effect on the cranial morphology and asymmetry of these birds. With a larger sample size (including more harrier species) and using parameters of soft tissues of the ear and temporal region will create a more complex vision regarding the evolution of asymmetrical features which are supporting directional hearing. New investigations reflecting on cranial asymmetries may increase our knowledge to understand how these special features are functioning in living specimens.

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The wing phalanges *(phalanx proximalis digiti majoris)* of Gaviiformes, Podicipediformes, Pelecaniformes, Ardeiformes, Anseriformes, Gruiformes, Ralliformes, Charadriiformes and Galliformes

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Abstract The authors compared the first phalanx of the second wing-finger of 93 species belong to 9 order (Gaviiformes – 2 species, Podicipediformes – 4 species, Pelecaniformes – 4 species, Ardeiformes – 12 species, Anseriformes – 27 species, Gruiformes – 4 species, Ralliformes – 6 species, Charadriiformes – 25 species and Galliformes – 9 species). The importance of studying this bone lies in the fact that, although it has diagnosable characteristics, it was practically neglected by osteologists and paleontologists. Thus, fossil materials can be identified through them, as well as those from owl pellets. The comparison was made possible by the comparative avian skeleton collection of the Hungarian Natural History Museum. The text is supplemented by 10 figures and 1 table.

Keywords: Europe, waterfowl, Galliformes, *phalanx proximalis digiti majoris*, osteology

Összefoglalás A szerzők 9 rendbe tartozó, összesen 93 madárfaj szárnyának második ujj első ujjpercét vetették összehasonlító vizsgálat alá (Gaviiformes – 2 faj, Podicipediformes – 4 faj, Pelecaniformes – 4 faj, Ardeiformes – 12 faj, Anseriformes – 27 faj, Gruiformes – 4 faj, Ralliformes – 6 faj, Charadriiformes – 25 faj, Galliformes – 9 faj). A vázrész tanulmányozásának jelentősége abban áll, hogy bár jól meghatározható jellegekkel rendelkezik, gyakorlatilag elhanyagolták a csonttannal és őslénytannal foglalkozók. Általuk mind recens, mind fosszilis anyagok jól meghatározhatóak. A vizsgálatot a Magyar Természettudományi Múzeum összehasonlító madárcsont gyűjtemény anyaga tette lehetővé. A szöveget 10 ábra és 1 táblázat egészíti ki.

Kulcsszavak: Európa, vízimadarak, tyúkalakúak, *phalanx proximalis digiti majoris*, csonttan

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Introduction

The current study discusses a less known part of the avian skeleton used for description. The bone is rather small (even in the case of the largest avian species it is only 6–7 centimeters long) and relatively simple in appearance. The first phalanx of the second wing-finger bears excellent diagnostic characteristics.

Out of the four wing phalanges, only this has such morphological characteristics that can be used for comparative anatomical, paleontological, archeological, taxonomical or ornithological examinations of owl pellets.

In this investigation the bird order Ardeiformes has traditionally been handled as distinct order from other bird groups due to their bone characters (Brodkorb 1963, Feduccia 1967). Recently, this classification has been used in the non-taxonomic sense because more recent studies suggested that herons are belonging to the order Pelecaniformes (Hackett *et al*. 2008, Smith 2010).

The morphological terminology and measurement method of the skeletal part was used based on the works of Baumel *et al.* 1979 and Kessler 2013 *(Figure 1/1–2)*. Depictions and discussions regarding the wing phalanx can only rarely be found within the literature, e.g. in the works of Milne-Edwards 1867–1868, Solti 1980, 1981a, 1981b, 1996, Gilbert *et al.* 1981, Cohen & Serjeantson 1996, Kessler 2015, 2016a, 2016b, 2019, 2020.

The sizes given in *Table 1* are for information purposes only. The measurement data are derived, on the one hand, from the weighing of specimens from the Natural History Museum of Hungary Budapest comparative bone collection and, on the other hand, from the dimensions of the wing span in the ornithological literature of the species concerned.

Abbreviations

MTM/NHMUS: Natural History Museum of Hungary Budapest, Department of Paleontology and Geology
A – total length
C – the width of the proximal end
E – the largest width of the middle phalanx
F – the width of the distal end
New genus, sp. name – Gill *et al.* 2020

We used the following anatomical terminology *(Figure 1)*:
Facies articularis metacarpalis – this is the proximal end
Margo dorsalis – this is the largest width of the middle phalanx
Facies articularis phalangealis – this is the distal end

Osteological description
In the case of loons, grebes, pelicans and cormorants *(Figure 2/1–10)*:
a). *Facies articularis metacarpalis*:
– strongly protuberant: *Podiceps auritus, P. grisegena*;

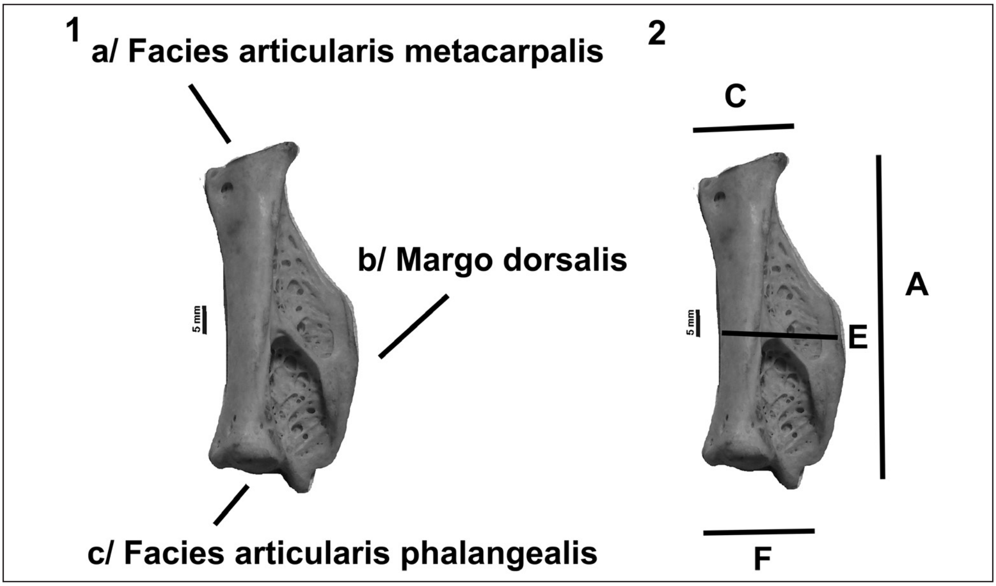

Figure 1. *Pelecanus onocrotalus* (Linnaeus, 1758)
1. *Phalanx proximalis digiti majoris* osteology characteristics:
a. proximal end – *facies articularis metacarpalis*; b. the dorsal side – *margo dorsalis*; c. distal end – *facies articularis phalangealis*;
2. Measurements methods of bone:
A. total length; C. breadth of the proximal end; E. breadth of the *corpus*; F. breadth of the distal end;

1. ábra *Pelecanus onocrotalus* (Linnaeus, 1758)
1. A nagy (középső) kézujj első ujjperce csonttani jellegei: a. proximális vég – *facies articularis metacarpalis*; b. dorzális oldal – *margo dorsalis*; c. disztális vég – *facies articularis phalangealis*;
2. A csont mérési mintái:
A. teljes hossz; C. proximális vég szélessége; E. a test szélessége; F. a disztális vég szélessége

– strongly protuberant, with a pointed cone shaped dorsal projection: *Gavia stellata*;
– slightly protuberant: *Gavia arctica*;
– with two bulges: *Phalacrocorax carbo*;
– obliquely cut, lifting from the ventral end towards the dorsal, ending in a pointed cone: *Pelecanus crispus, P. onocrotalus, Podiceps nigricollis*;
– obliquely cut, lifting from the ventral end towards the dorsal, ending in a blunt cone: *Phalacrocorax pygmaeus*;
– concave with a dorsal and a ventral pointed projection: *Podiceps cristatus*;

b). *Margo dorsalis*:
– forms a regular arc: *Gavia stellata, Phalacrocorax carbo*;
– the arc is strongly protuberant and is asymmetrical: *Pelecanus crispus, P. onocrotalus*;
– has a regular arc, is slightly protuberant: *Podiceps cristatus, P. grisegena, P. nigricollis*;
– the middle of the arc is cut straight: *Gavia arctica, Podiceps auritus*;
– the slightly protuberant arc is wavy: *Phalacrocorax pygmeus*;

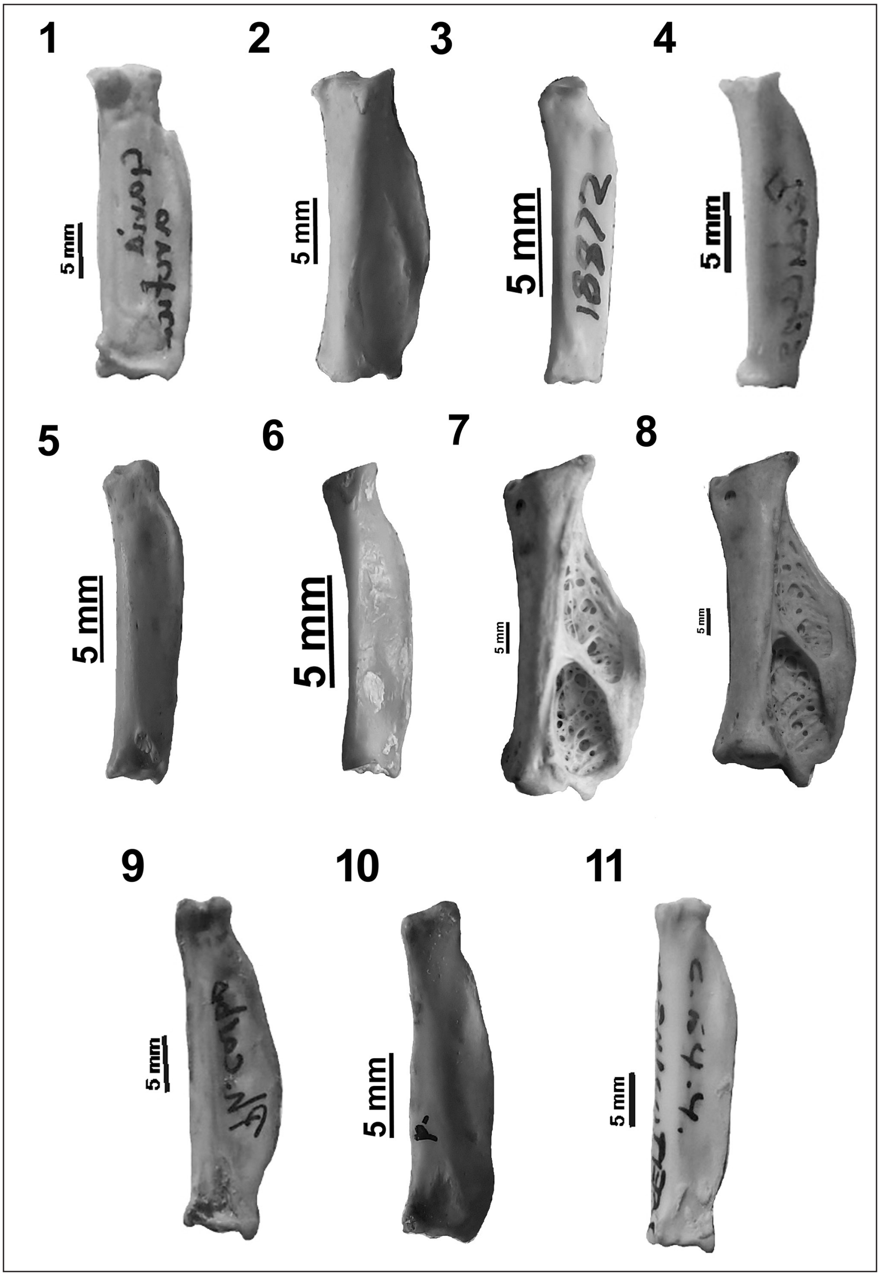

Figure 2. Left *phalanx proximalis digiti majoris* (ventral aspect)
2. ábra Bal oldali kézujjperc (1. ujjperc, II. ujj, hasi nézet)
1. *Gavia arctica* (Linnaeus, 1758); 2. *Gavia stellata* (Pontoppidan, 1753); 3. *Podiceps auritus* (Linnaeus, 1758); 4. *Podiceps cristatus* (Linnaeus, 1758); 5. *Podiceps grisegena* (Boddaert, 1783); 6. *Podiceps nigricollis* (Brehm, 1831); 7. *Pelecanus crispus* (Bruch, 1832); 8. *Pelecanus onocrotalus* (Linnaeus, 1758); 9. *Phalacrocorax carbo* (Shaw *et* Nodder, 1801); 10. *Phalacrocorax pygmaeus* (Pallas, 1773); 11. *Phoenicopterus ruber* (Pallas, 1811)

c). *Facies articularis phalangealis*:
- – oblique, with a strongly protruding dorsal projection: *Pelecanus onocrotalus*;
- – straight, strongly protuberant, with a small dorsal projection: *Gavia stellata, Pelecanus crispus*;
- – wavy, with a strongly protruding dorsal and ventral projection: *Phalacrocorax carbo*;
- – wavy, with a slightly protruding dorsal projection: *Gavia arctica*; *Phalacrocorax pygmeus, Podiceps auritus, P. cristatus, P. grisegena, P. nigricollis*;

In the case of herons, ibises, flamingos *(Figure 2/11, Figure 3/1–11*):
a). *Facies articularis metacarpalis*:
- – strongly protuberant: *Bubulcus* spp*., Ciconia nigra*;
- – strongly protuberant, pointed, with a small dorsal projection pointing upward: *Ardeola* spp.;
- – slightly protuberant, with a rounded ventral end: *Phoenicopterus* spp., *Plegadis* spp.;
- – a straight, protuberant ventral and a small pointed projection pointing upward: *Botaurus* spp.;
- – obliquely cut, lifting from the ventral end towards the dorsal: *Ciconia ciconia, Platalea* spp.;
- – straight and wavy: *Ardea purpurea*;
- – oblique and wavy: *Ardea cinerea, Egretta* spp.;
- – oblique and wavy, with a strongly protruding pointed dorsal and ventral projection: *Nycticorax*;

b). *Margo dorsalis*:
- – forms a regular, strongly protuberant arc: *Bubulcus* spp*., Botaurus* spp*., Plegadis* spp.;
- – the ark is slightly protuberant: *Platalea* spp.;
- – asymmetrically protuberant: *Ciconia nigra*;
- – the middle of the arc is cut straight: *Ardea cinerea, A. purpurea, Ardeola* spp*., Ciconia ciconia, Egretta* spp*., Nycticorax* spp*., Phoenicopterus* spp.;

c). *Facies articularis phalangealis*:
- – oblique, with a strongly protruding dorsal projection: *Bubulcus* spp*., Ciconia ciconia, C. nigra*;
- – straight wavy, with a slightly protruding dorsal projection: *Ardea cinerea, A. purpurea, Ardeola* spp*., Botaurus* spp*., Egretta* spp*., Nycticorax* spp*., Platalea* spp.;
- – straight wavy, with a strongly protruding dorsal projection: *Phoenicopterus* spp*.,*
- – concave, with a strongly protruding dorsal projection: *Plegadis* spp.;

In the case of geese, swans, shelducks *(Figure 4/1–9)*:
a). Shape of *facies articularis metacarpalis*:
- – oblique and wavy: *Anser albifrons*;
- – cut straight with an oblique, strongly protruding dorsal tip: *Anser erythropus, A. fabalis, Branta ruficollis*;
- – cut straight with an oblique, slightly protruding dorsal tip: *Anser anser, Cygnus cygnus*;
- – protuberant, with a strongly protruding dorsal projection: *Tadorna* spp.;
- – slightly protuberant, with a small dorsal projection pointing upward: *Branta bernicla*;
- – slightly concave: *Cygnus olor*;

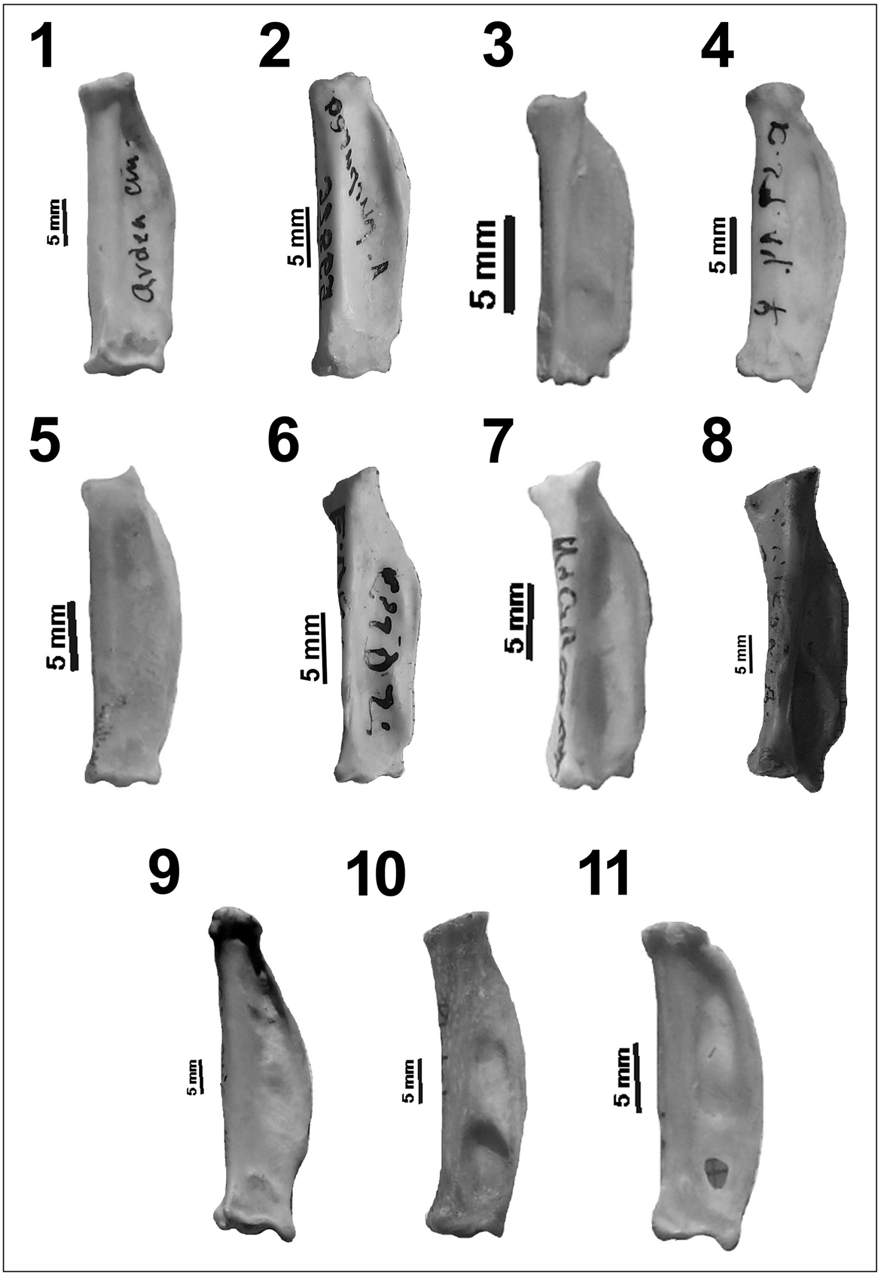

Figure 3. Left *phalanx proximalis digiti majoris* (ventral aspect)

3. ábra Bal oldali kézujjperc (1. ujjperc, II. ujj, hasi nézet)

1. *Ardea cinerea* (Linnaeus, 1758); 2. *Ardea purpurea* (Linnaeus, 1758); 3. *Ardeola ralloides* (Scopoli, 1769); 4. *Bubulcus ibis* (Linnaeus, 1758); 5. *Botaurus stellaris* (Linnaeus, 1758); 6. *Egretta garzetta* (Linnaeus, 1766); 7. *Nycticorax nycticorax* (Linnaeus, 1758); 8. *Ciconia ciconia* (Linnaeus, 1758); 9. *Ciconia nigra* (Linnaeus, 1758); 10. *Platalea leocorodia* (Linnaeus, 1758); 11. *Plegadis falcinellus* (Linnaeus, 1766)

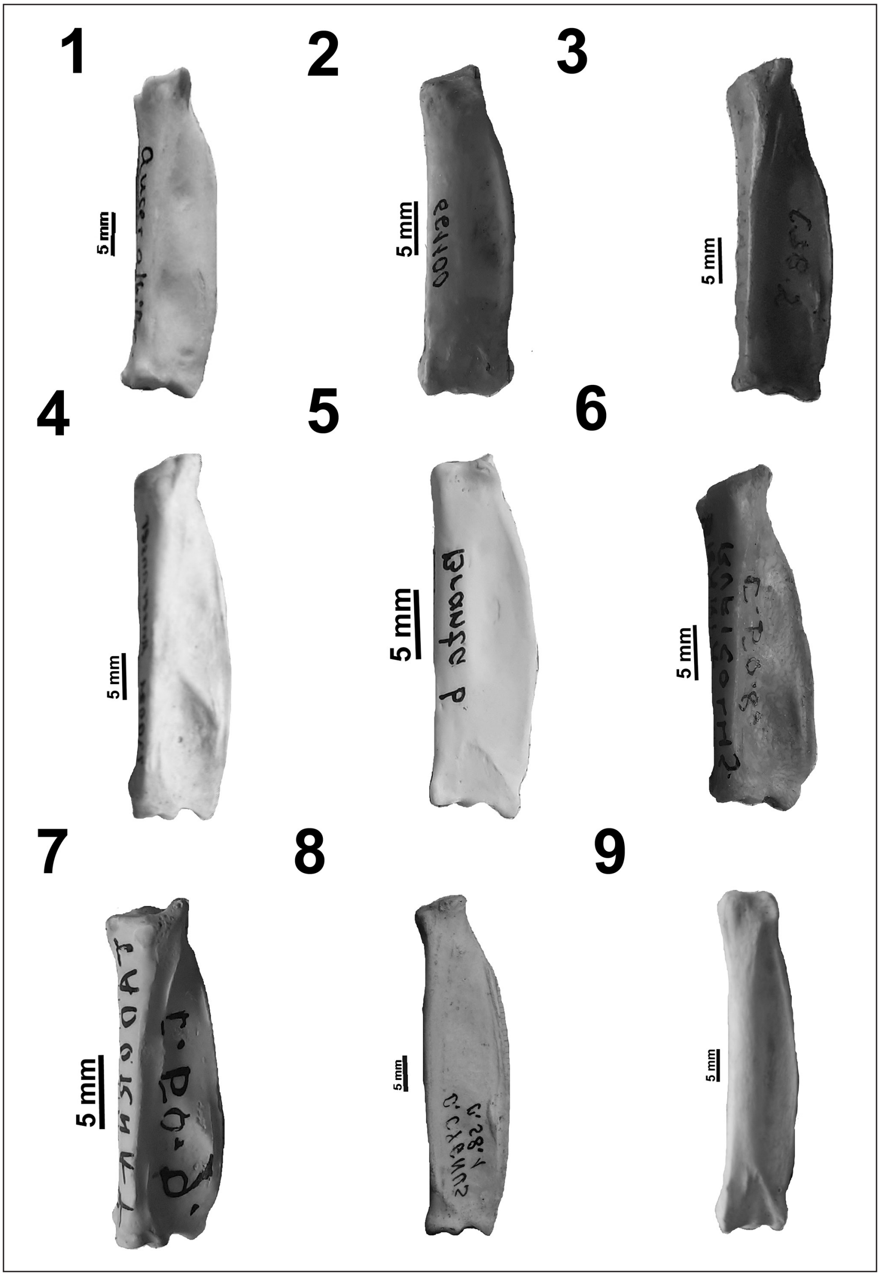

Figure 4. Left *phalanx proximalis digiti majoris* (ventral aspect)
4. ábra Bal oldali kézujjperc (1. ujjperc, II. ujj, hasi nézet)
1. *Anser albifrons* (Scopoli, 1769); 2. *Anser anser* (Linnaeus, 1758); 3. *Anser erythropus* (Linnaeus, 1758); 4. *Anser fabalis* (Latham, 1790); 5. *Branta bernicla* (Linnaeus, 1758); 6. *Branta ruficollis* (Pallas, 1769); 7. *Tadorna tadorna* (Linnaeus, 1758); 8. *Cygnus cygnus* (Linnaeus, 1758); 9. *Cygnus olor* (Gmelin, 1789)

b). The arc of the *margo dorsalis*:
- strongly protuberant: *Anser erythropus, Branta bernicla, B. ruficollis, Tadorna* spp.;
- moderately protuberant: *Anser albifrons, A. anser, A. fabalis, Cygnus cygnus*;
- slightly protuberant: *Cygnus olor*;

c). The shape of the *facies articularis phalangealis*:
- symmetrically wavy, with a slightly protruding dorsal projection: *Anser albifrons, A. anser, A. erythropus, A. fabalis, Branta ruficollis, Cygnus cygnus, C. olor*;
- symmetrically wavy, with a strongly protruding dorsal projection: *Branta bernicla*;
- asymmetrically wavy: *Tadorna* spp.;

In the case of diving ducks, tumblers *(Figure 5/1–11)*:

a). Shape of *facies articularis metacarpalis*:
- slightly obliquely cut: *Anas acuta, A. platyrhynchos*;
- strongly obliquely cut, with a small pointed ventral and well-developed blunt dorsal projection: *Anas clypeata*;
- strongly obliquely cut, with a well-developed pointed dorsal projection: *Anas strepera*;
- slightly protuberant and obliquely cut, with a well-developed pointed dorsal projection: *Aythya ferina*;
- straight, with a small, pointed conelike projection: *Anas querquedula, Aythya nyroca*;
- strongly protuberant: *Aythya fuligula*;
- slightly protuberant: *Aythya marila*;
- concave: *Anas crecca, A. penelope*;

b). The arc of the *margo dorsalis*:
- the bulge is cut: *Anas crecca*;
- strongly protuberant, slightly wavy: *Anas clypeata, A. penelope, A. querquedula, A. strepera*;
- moderately and regularly protuberant: *Anas acuta, Aythya ferina, A. nyroca*;
- slightly protuberant: *Anas platyrhynchos, Aythya fuligula, A. marila*;

c). The shape of the *facies articularis phalangealis*:
- cut straight, slightly wavy, with a well-developed dorsal projection: *Anas acuta, A. clypeata, A. crecca, A. penelope, A. platyrhynchos, A. querquedula, A. strepera, Aythya ferina, A. fuligula*;
- cut straight, slightly wavy, with an underdeveloped dorsal projection: *Aythya marila, A. nyroca*;

In the case of sea ducks, mergansers *(Figure 6/1–7)*:

a). Shape of *facies articularis metacarpalis*:
- slightly obliquely cut with a runded dorsal projection: *Mergellus albellus*;
- strongly obliquely cut, with a runded ventral and well-developed pointed dorsal projection: *Bucephala* spp.;
- strongly obliquely cut, with a weakly-developed pointed dorsal projection: *Melanitta* spp.;
- slightly protuberant and obliquely cut, with a well-developed pointed dorsal projection: *Clangula* spp.;

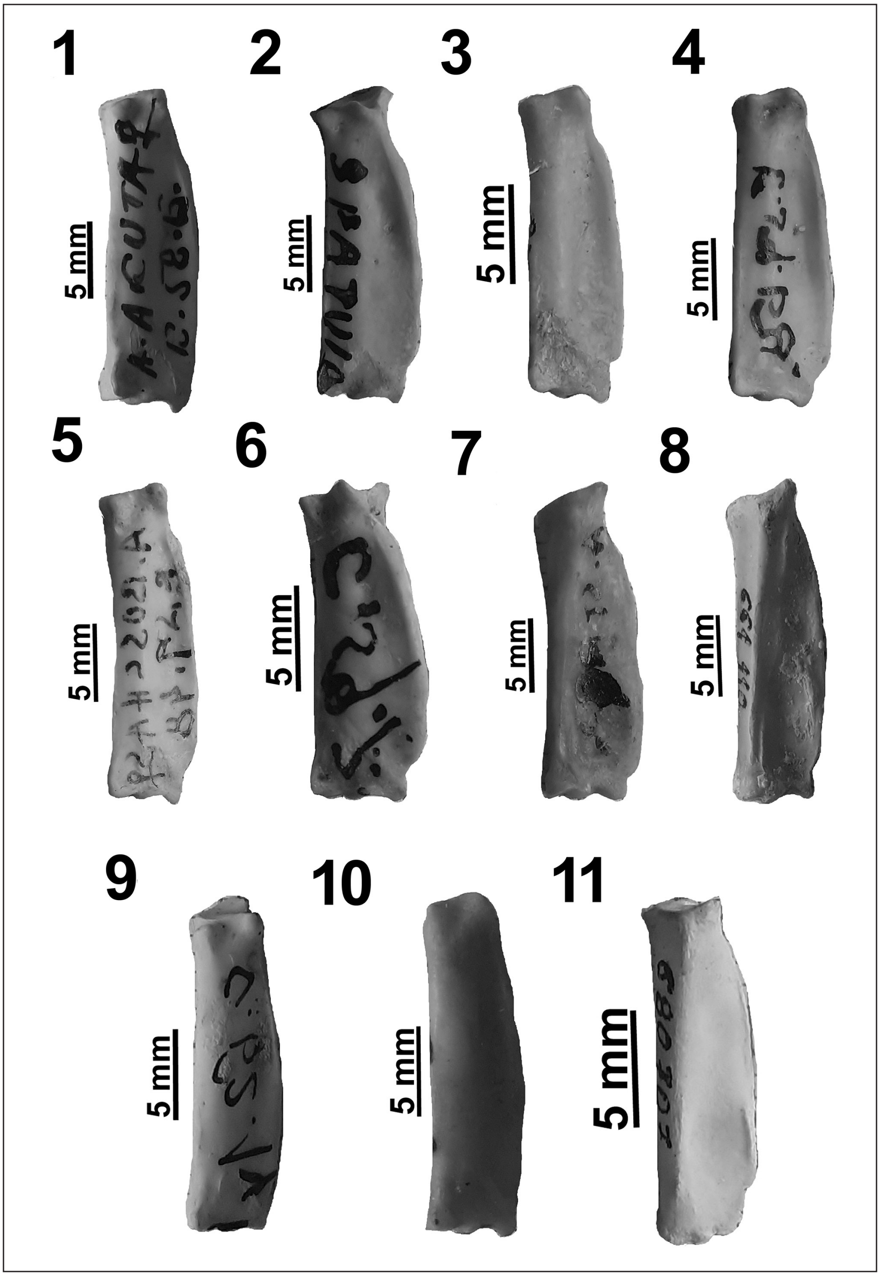

Figure 5. Left *phalanx proximalis digiti majoris* (ventral aspect)

5. ábra Bal oldali kézujjperc (1. ujjperc, II. ujj, hasi nézet)

1. *Anas acuta* (Linnaeus, 1758); 2. *Anas clypeata* (Linnaeus, 1758); 3. *Anas crecca* (Linnaeus, 1758); 4. *Anas penelope* (Linnaeus, 1758); 5. *Anas plathyrhynchos (*Linnaeus, 1758); 6. *Anas strepera* (Linnaeus, 1758); 7. *Anas querquedula* (Linnaeus, 1758); 8. *Aythya ferina* (Linnaeus, 1758); 9. *Aythya fuligula* (Linnaeus, 1758); 10. *Aythya marila* (Linnaeus, 1761); 11. *Aythya nyroca* (Güldenstadt, 1769)

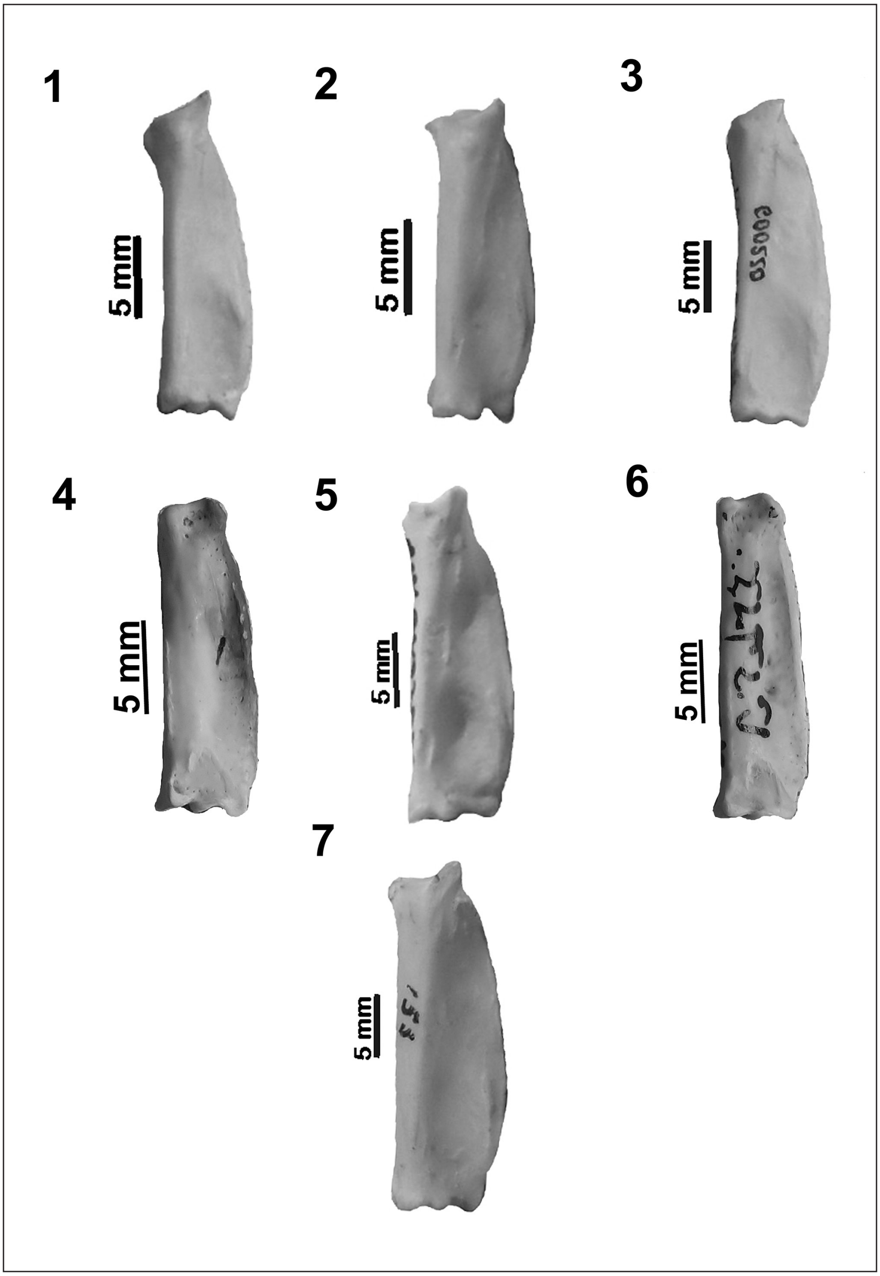

Figure 6. Left *phalanx proximalis digiti majoris* (ventral aspect)
6. ábra Bal oldali kézujjperc (1. ujjperc, II. ujj, hasi nézet)
1. *Bucephala clangula* (Linnaeus, 1758); 2. *Clangula hyemalis* (Linnaeus, 1758); 3. *Mellanita nigra* (Linnaeus, 1758); 4. *Mergus albellus* (Linnaeus, 1758); 5. *Mergus merganser* (Linnaeus, 1758); 6. *Mergus serrator* (Linnaeus, 1758); 7. *Somateria mollissima* (Linnaeus, 1758)

– straight, with a pointed conelike projection: *Mergus merganser, Somateria* spp.;
– concave: *Mergus serrator*;
b). The arc of the *margo dorsalis*:
– the bulge cut obliquely: *Mergus serrator*;
– strongly and regularly protuberant: *Bucephala* spp.*, Clangula* spp.*, Melanitta* spp.*, Mergus merganser, Somateria* spp.;
– slightly protuberant: *Mergellus albellus*;
c). The shape of the *facies articularis phalangealis*:
– cut straight, wavy, with a well-developed dorsal projection: *Bucephala* spp., *Clangula* spp.;
– cut straight, slightly wavy, with an underdeveloped dorsal projection: *Melanitta*, *Mergellus albellus, M. merganser, M. serrator, Somateria* spp.;

In the case of cranes, bustards, coots, rails *(Figure 7/1–10)*:
a). Shape of *facies articularis metacarpalis*:
– obliquely cut, with a well-developed dorsal pointed tip: *Otis tarda, O. tetrax*;
– obliquely cut, with a slightly developed dorsal pointed tip: *Porzana parva, P. porzana*;
– obliquely cut, with a blunt dorsal tip: *Anthropoides* spp.;
– slightly obliquely cut, with a slight bulge, with a pointed dorsal tip: *Grus* spp.;
– small, pointed tip in the middle: *Fulica* spp.*, Gallinula* spp.*, Rallus* spp.;
– large, pointed tip in the middle: *Crex* spp.;
b). The arc of the *margo dorsalis*:
– the strong bulge is cut: *Crex* spp.;
– the slight bulge is cut: *Fulica* spp.*, Gallinula* spp.;
– wide, regular bulge: *Porzana parva, P. porzana, Rallus aquaticus*;
– moderate, regular bulge: *Anthropoides* spp.*, Grus, Otis tarda, O. tetrax*;
c). The shape of the *facies articularis phalangealis*:
– slightly wavy and oblique, with a protruding dorsal projection: *Anthropoides* spp.*, Grus* spp.*, Otis tarda, O. tetrax*;
– straight and wavy: *Crex* spp.*, Gallinula* spp.*, Porzana porzana, Rallus* spp.;
– slightly protuberant, with a small pointed ventral tip: *Fulica* spp.;
– strongly protuberant, with an unrounded protruding ventral end: *Porzana parva*;

In the case of plowers, shanks, sandpipers, terns, marsh terns, and auks *(Figure 7/11, Figure 8/1–12, Figure 9/1–6)*:
a). Shape of *facies articularis metacarpalis*:
– strongly protuberant, with a large and pointed dorsal projection: *Calidris* spp.*, Charadrius* spp.;
– strongly protuberant, with a small and pointed dorsal projection: *Lymnocryptes* spp.;
– slightly protuberant, with a small and pointed dorsal projection: *Arenaria* spp.*, Gallinago* spp.*, Himantopus* spp.;
– slightly protuberant: *Tringa erythropus, T. totanus*;
– strongly oblique, with a well-developed and pointed dorsal projection: *Glareola* spp.*, Philomachu* spp.*s, Pluvialis* spp.*, Recurvirostra* spp.;
– oblique and slightly protuberant, with a protruding dorsal projection: *Tringa hypoleucos*;

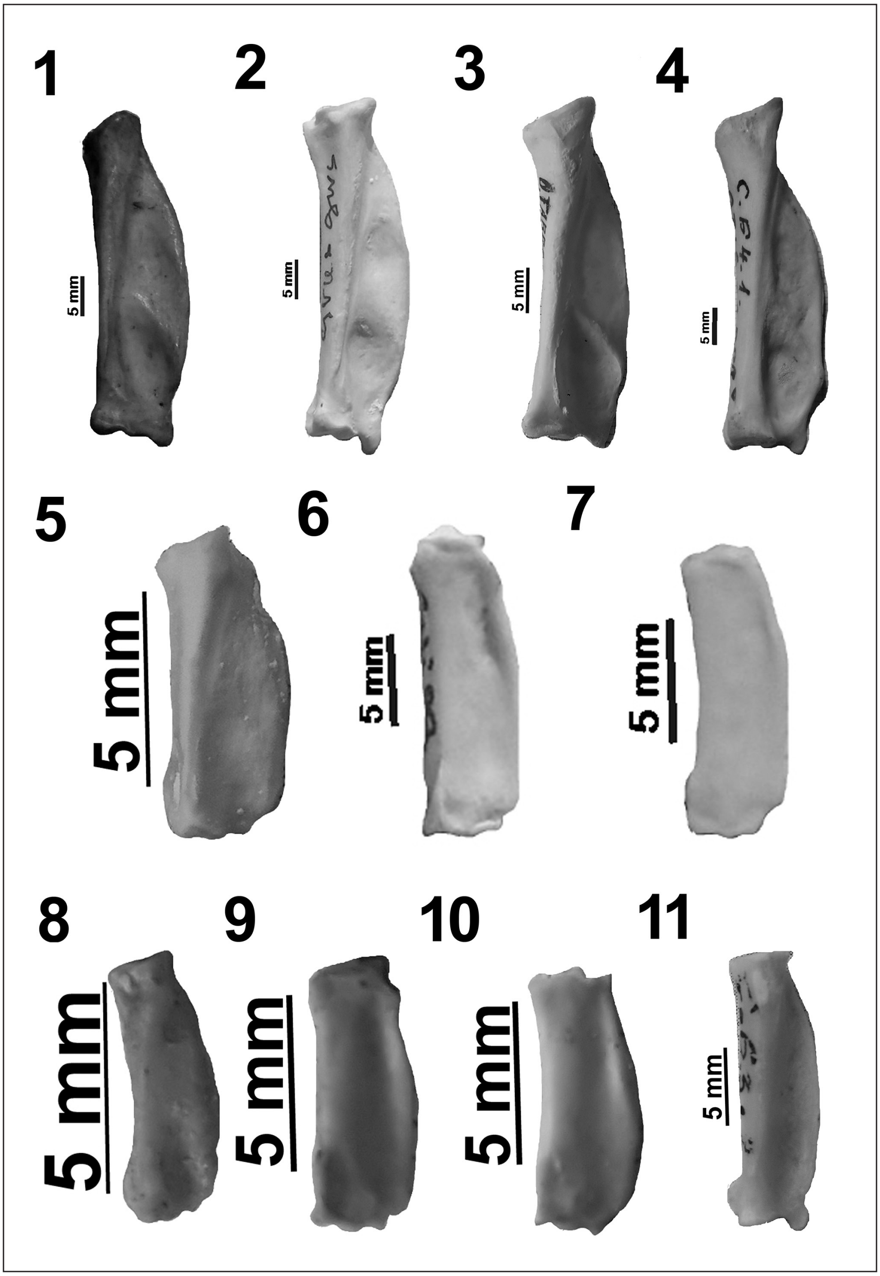

Figure 7. Left *phalanx proximalis digiti majoris* (ventral aspect)
7. ábra Bal oldali kézujjperc (1. ujjperc, II. ujj, hasi nézet)
1. *Anthropoides virgo* (Linnaeus, 1758); 2. *Grus grus* (Linnaeus, 1758); 3. *Otis tarda* (Linnaeus, 1758); 4. *Otis tetrax* (Linnaeus, 1758); 5. *Crex crex* (Linnaeus, 1758); 6. *Fulica atra* (Linnaeus, 1758); 7. *Gallinula chloropus* (Linnaeus, 1758); 8. *Porzana parva* (Scopoli, 1769); 9. *Porzana porzana* (Linnaeus, 1758); 10. *Rallus aquaticus* (Linnaeus, 1758); 11. *Uria aalge* (Pontoppidan, 1763)

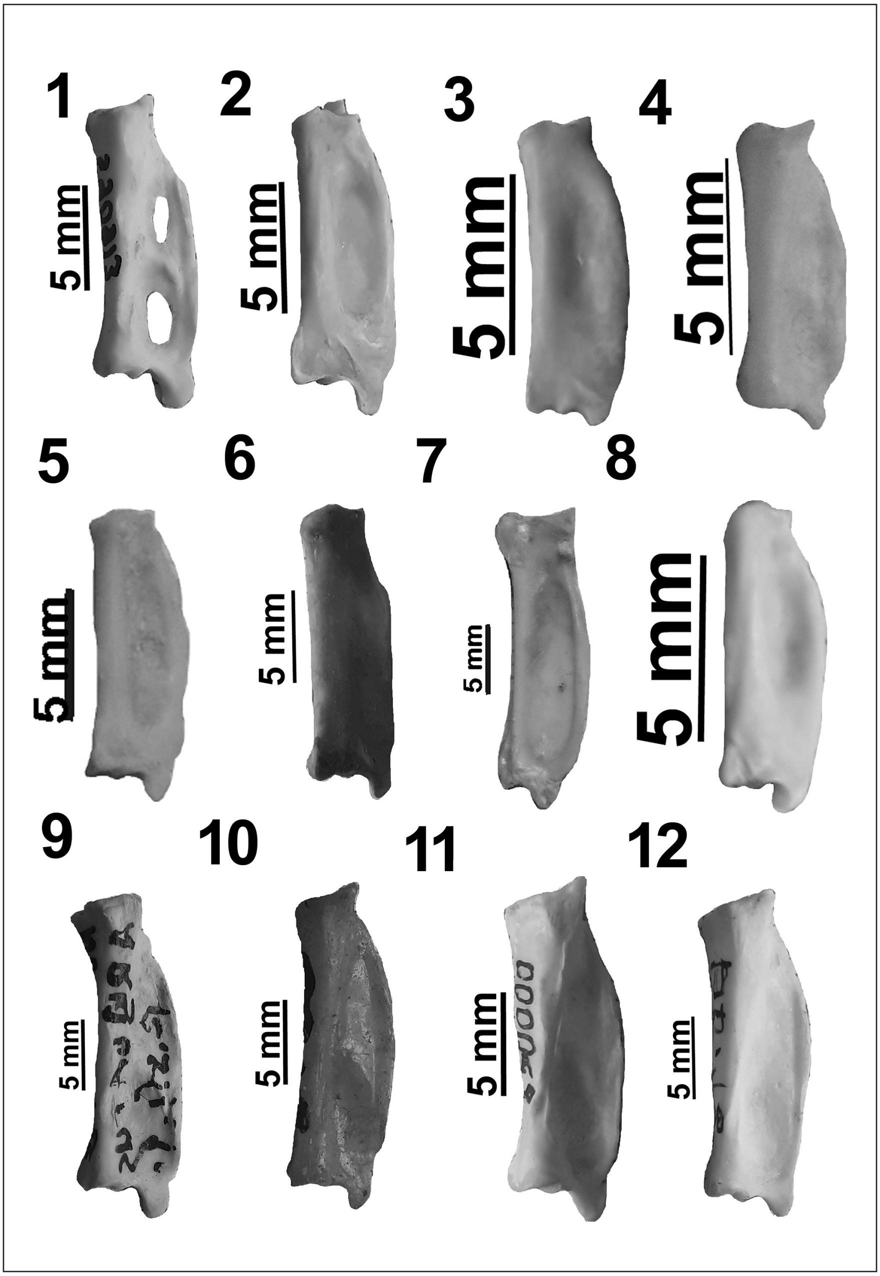

Figure 8. Left *phalanx proximalis digiti majoris* (ventral aspect)
8. ábra Bal oldali kézujjperc (1. ujjperc, II. ujj, hasi nézet)
1. *Glareola pratincola* (Linnaeus, 1766); 2. *Arenaria intrepres* (Linnaeus, 1758); 3. *Calidris alpina* (Brehm, 1822); 4. *Charadrius alexandrinus* (Linnaeus, 1758); 5. *Gallinago gallinago* (Linnaeus, 1758); 6. *Himantopus himantopus* (Linnaeus, 1758); 7. *Limosa limosa* (Linnaeus, 1758); 8. *Lymnocryptes minimus* (Brünnich, 1764); 9. *Numenius arquatus* (Linnaeus, 1758); 10. *Phylomachus pugnax* (Linnaeus, 1758); 11. *Pluvialis squatarola* (Linnaeus, 1758); 12. *Recurvirostra avosetta* (Linnaeus, 1758)

– oblique, with a well-developed and blunt dorsal projection: *Scolopax* spp.;
– slightly obliquely cut, with a straight ventral end and a small dorsal tip: *Numenius* spp.;
– concave: *Limosa* spp.*, Tringa nebularis*;
– with a strongly protruding pointed conelike tip on the ventral side: *Vanellus* spp.;
– straight, with a dorsally protruding small pointed projection: *Uria* spp.;
b). The arc of the *margo dorsalis*:
– the bulge is cut: *Glareola* spp.*, Arenaria* spp.*, Himantopus* spp.*, Vanellus* spp.;
– the arc of the bulge is symmetrical: *Calidris* spp.*, Charadrius* spp.*, Gallinago* spp.*, Lymnocryptes* spp.*, Limosa* spp.*, Numenius* spp.*, Philomachus* spp.*, Pluvialis* spp.*, Recurvirostra* spp.*, Scolopax* spp.*, Tringa erythropus, T. hypoleucos, T. nebularia, T. totanus, Uria* spp.;
c). The shape of the *facies articularis phalangealis*:
– wavy, with a slightly protruding dorsal projection: *Calidris* spp.;
– wavy, with a strongly protruding, blunt dorsal projection: *Glareola* spp.*, Arenaria* spp.*, Charadrius* spp.*, Gallinago* spp.*, Himmantopus* spp.*, Lymnocryptes* spp.*, Limosa* spp.*, Numenius* spp.*, Phylomachus* spp.*, Pluvialis* spp.*, Recurvirostra* spp.*, Scolopax* spp.*, Vanellus* spp.*, Tringa erythropus, T. hypoleucos, T. nebularia, T. totanus*;
– convex, with a protuberant ventral and bluntly protruding dorsal projection: *Uria* spp.;

In the case of seagulls and skuas *(Figure 9/7–12)*:
a). Shape of *facies articularis metacarpalis*:
– oblique and slightly protuberant, with a protruding dorsal projection: *Larus minutus, L. ridibundus, Stercorarius* spp.;
– oblique, with a well-developed and pointed dorsal projection: *Chlidonias* spp.*, Larus canus*;
– asymmetrically protruding in the middle: *Sterna* spp.;
b). The arc of the *margo dorsalis*:
– the bulge is cut: *Larus minutus, Sterna* spp.;
– the bulge has a symmetrical arc: *Chlidonias* spp.*, Larus canus, L. ridibundus, Stercorarius* spp.;
c). The shape of the *facies articularis phalangealis*:
– slightly obliquely convex, with a well-developed and blunt ventral and dorsal projection: *Chlidonias* spp.*, Larus canus, L. minutus, L. ridibundus, Stercorarius* spp.*, Sterna* spp.;

In the case of partridges, quails and junglefowls *(Figure 10/1–4)*:
a). Shape of *facies articularis metacarpalis*:
– concave: *Gallus* spp.;
– straight line: *Alectoris* spp.;
– obliquely wavy, lifting from the ventral end towards the dorsal: *Coturnix* spp.;
– straight wavy: *Perdix* spp.;
b). The arc of the *margo dorsalis*:
– slightly protuberant and forms a regular arc: *Alectoris* spp.;
– the arc is regularly and strongly protuberant: *Gallus* spp.;

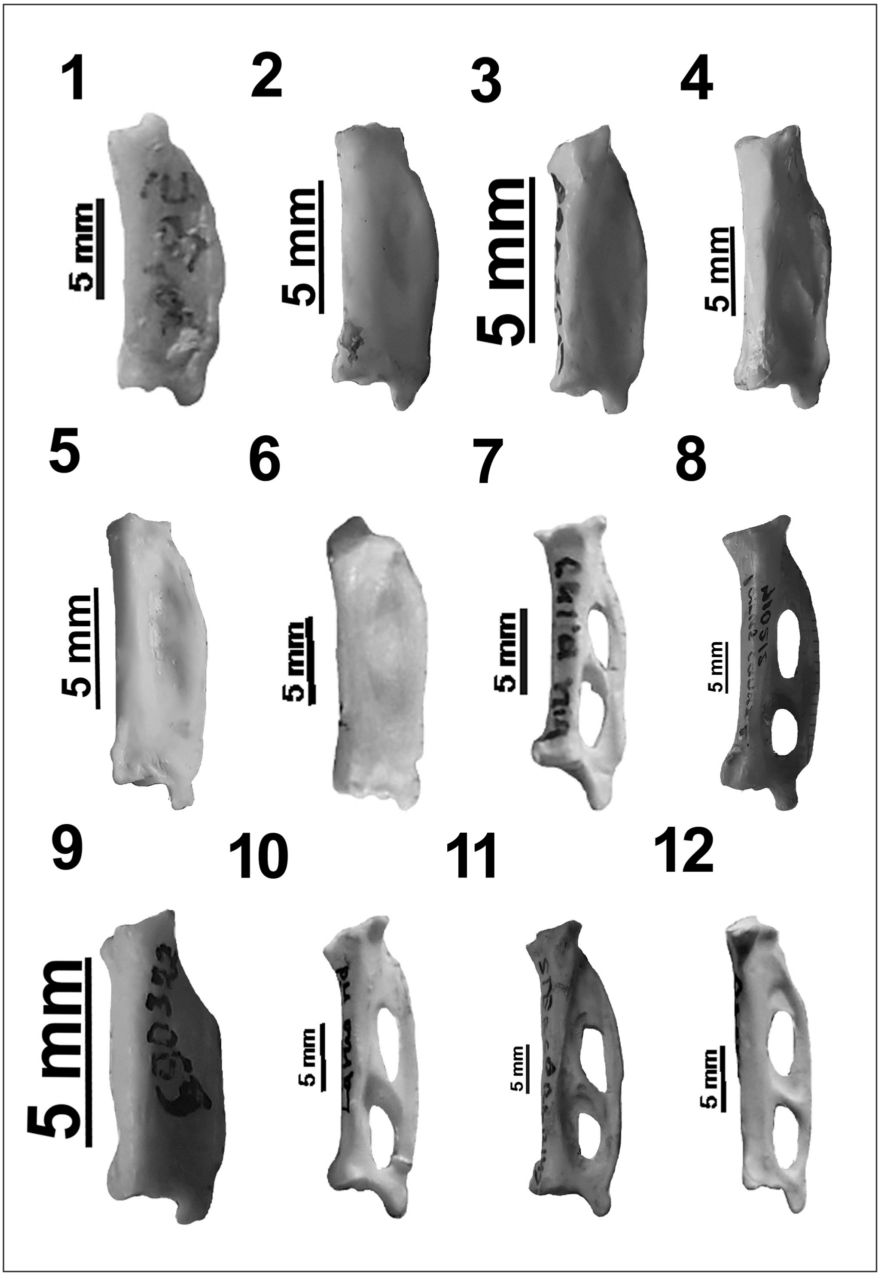

Figure 9. Left *phalanx proximalis digiti majoris* (ventral aspect)
9. ábra Bal oldali kézujjperc (1. ujjperc, II. ujj, hasi nézet)
1. *Scolopax rusticola* (Linnaeus, 1758); 2. *Tringa erythropus* (Pallas, 1764); 3. *Tringa hypoleucos* (Linnaeus, 1758); 4. *Tringa nebularia* (Gunnerus, 1767); 5. *Tringa totanus* (Linnaeus, 1758); 6. *Vanellus vanellus* (Linnaeus, 1758); 7. *Chlidonias niger* (Linnaeus, 1758); 8. *Larus canus* (Linnaeus, 1758); 9. *Larus minutus* (Pallas, 1766); 10. *Larus ridibundus* (Linnaeus, 1758); 11. *Stercorarius pomarinus* (Temminck, 1815); 12. *Sterna hirundo* (Linnaeus, 1758)

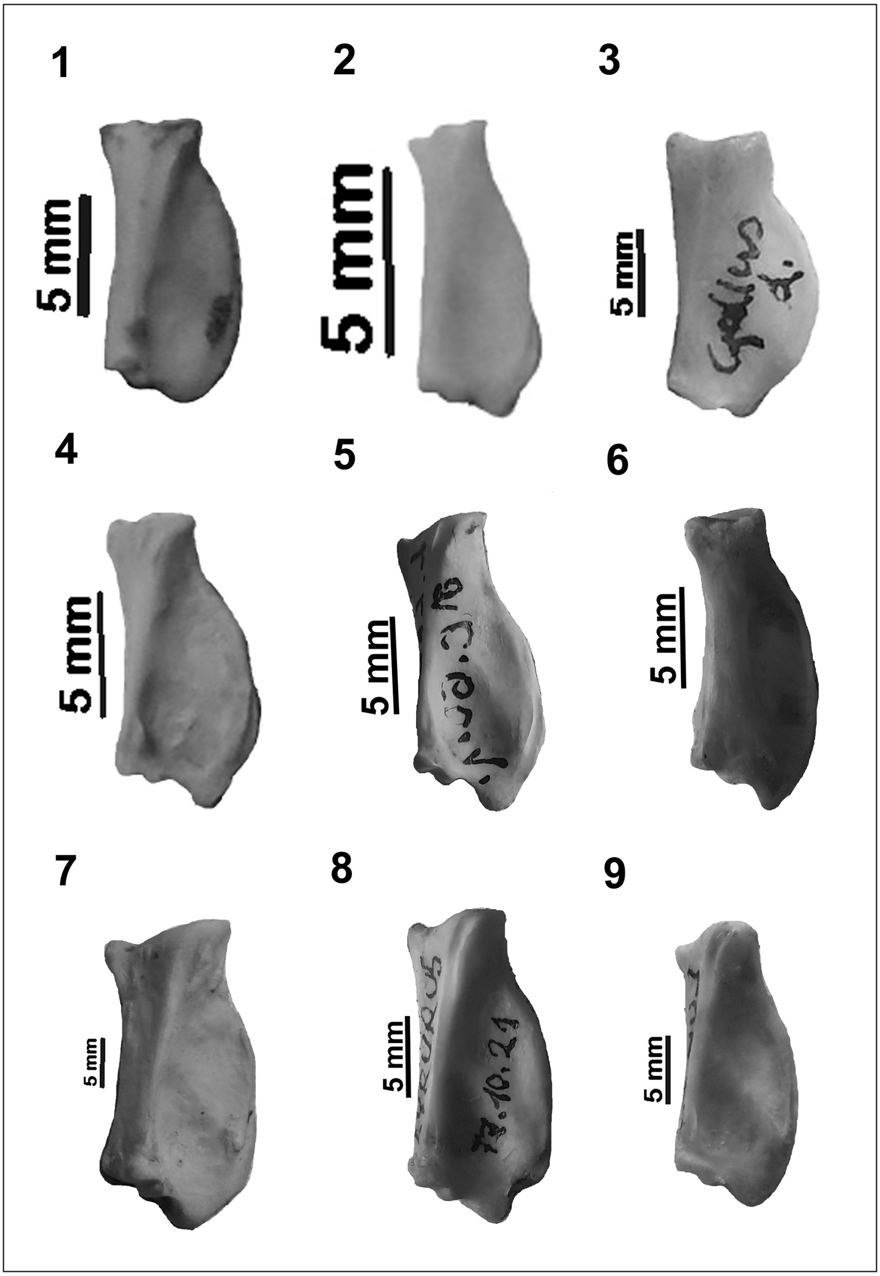

Figure 10. Left *phalanx proximalis digit majoris* (ventral aspect)
10. ábra Bal oldali kézujjperc (1. ujjperc, II. ujj, hasi nézet)
1. *Alectoris graeca* (Meisner, 1804); 2. *Coturnix coturnix* (Linnaeus, 1758); 3. *Gallus gallus domesticus* (Linnaeus, 1758); 4. *Perdix perdix* (Linnaeus, 1758); 5. *Lagopus lagopus* (Linnaeus, 1758); 6. *Lagopus mutus* (Montin, 1776); 7. *Tetrao urogallus* (Linnaeus, 1758); 8. *Tetrao tetrix* (Linnaeus, 1758); 9. *Tetrastes bonasia* (Linnaeus, 1758)

– the slightly and irregularly protuberant arc is wavy: *Coturnix* spp.;
– the strongly and irregularly protuberant arc is wavy: *Perdix* spp.;
c). The shape of the *facies articularis phalangealis*:
– obliquely wavy, with a strongly protruding dorsal projection: *Perdix* spp.;
– obliquely wavy, with a slightly protruding dorsal projection: *Alectoris* spp*.,* *Gallus* spp.;
– obliquely straight, with a slightly protruding dorsal projection: *Coturnix* spp.;

In the case of grouse *(Figure 10/5–9)*:
a). Shape of *facies articularis metacarpalis*:
– obliquely and slightly protuberant, with a strongly protruding ventral tip: *Tetrao* spp.;
– strongly protuberant, with an slightly protruding ventral projection: *Tetrastes* spp.;
– obliquely cut straight, with a slightly protruding ventral projection: *Lagopus* spp.;
b). The arc of the *margo dorsalis*:
– forms a strongly protuberant and regular arc: *Tetrastes* spp.;
– strongly protuberant, with an obliquely cut edge: *Lagopus* spp.;
– strongly protuberant with a slightly oblique and flattened edge: *Tetrao* spp.;
c). Shape of *facies articularis phalangealis*:
– obliquely wavy, with a strongly protruding conelike dorsal projection: *Lagopus* spp.;
– obliquely wavy, with a strongly protruding blunt conelike dorsal projection: *Tetrao* spp.;
– obliquely wavy, with a rounded protruding dorsal projection: *Tetrastes* spp.;

Conclusions

In the case of examined waterbird species, the shape and size of the *phalanx* is quite diverse. We can examine significant cases of sexual dimorphism *(Otis)* in certain species. This greatly favors male specimen. It may be expedient to compare the changes in form of the examined characteristics with the differences in size, since there can be significant differences within families or even genera. Similarities in form can occur in species of different families or genera.

The first *phalanx* of the second wing-finger of Galliformes is typically short and wide, with the exception of the *Coturnix* wing phalanx, which is longer and slimmer. In the case of Phasianidae, the shape proximal end is diverse, while the dorsal edge forms a strongly protuberant arc. The distal end obliquely descends to the dorsal projection, which is more or less strongly protruding. The proximal end in the case of Tetraonidae has a diverse form. The dorsal edge is strongly protuberant but different, while the distal end is descending in an oblique and wavy fashion to the dorsal projection, which is quite strongly protuberant but differs in shape.

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Table 1. Size table of *phalanx proximalis digiti majoris*
A – total length of bone (mm); C – breadth of proximal end; E – breadth of corpus; F – breadth of distal end. New name (Gill *et al*. 2020)

1. táblázat A *phalanx proximalis digiti majoris* mérettáblázata
A – teljes hossz (mm); C – proximális vég szélessége; E – a test szélessége; F – disztális vég szélessége. Új név – New name (Gill *et al*. 2020)

Species	New genus name	A	C	E	F
	Gill *et al.* 2019				
Gaviiformes					
Gavia arctica		26.50	5.50	8.00	7.00
Gavia stellata		22.50	6.00	7.00	5.50
Podicipediformes					
Podiceps auritus		14.20	2.50	3.00	2.50
Podiceps cristatus		20.00	3.50	4.50	3.70
Podiceps grisegena		19.00	3.00	4.00	3.00
Podiceps nigricollis		15.00	2.50	3.00	2.50
Pelecaniformes					
Pelecanus crispus		68.00	17.00	26.00	16.00
Pelecanus onocrotalus		71.00	18.00	26.00	18.00
Phalacrocorax carbo		33.00	6.00	9.00	6.50
Phalacrocorax pygmaeus	*Microcarbo*	19.50	3.50	6.00	4.00
Ardeiformes					
Ardea cinerea		35.00	6.50	11.00	8.00
Ardea purpurea		28.00	4.50	9.00	7.00
Ardeola ralloides		16.00	3.00	5.00	3.50
Bubulcus ibis		31.00	6.00	10.00	8.00
Botaurus stellaris		27.00	4.50	7.50	6.00
Egretta garzetta		20.50	5.00	6.00	5.00
Nycticorax nycticorax		20.00	3.00	10.50	5.00
Ciconia ciconia		46.00	11.00	11.50	11.00
Ciconia nigra		50.00	8.00	13.00	12.00
Platalea leucorodia		39.00	8.00	10.50	8.00
Plegadis falcinellus		22.00	3.50	7.50	5.00
Phoenicopterus ruber		36.00	5.00	8.00	6.00
Anseriformes					
Anser albifrons		40.00	7.00	11.50	11.00
Anser anser		46.00	9.50	10.50	10.00

Species	New genus name	A	C	E	F
Anser erythropus		33.00	6.00	10.00	7.00
Anser fabalis		41.00	7.50	11.50	10.00
Branta bernicla		29.00	5.00	9.00	7.00
Branta ruficollis		25.00	6.50	7.50	5.50
Tadorna tadorna		34.00	6.00	10.50	8.00
Cygnus cygnus		61.00	10.50	15.00	11.00
Cygnus olor		59.00	11.00	12.00	11.00
Anas acuta		22.00	3.50	6.50	6.00
Anas clypeata	*Spatula*	20.50	5.00	5.50	5.00
Anas crecca		15.00	3.00	5.00	4.00
Anas penelope	*Mareca*	20.00	4.00	6.50	4.00
Anas platyrhynchos		23.00	4.50	7.00	5.00
Anas querquedula	*Spatula*	15.00	4.00	6.00	4.50
Anas strepera	*Mareca*	21.00	4.50	6.50	5.00
Aythya ferina		19.50	4.00	5.50	4.50
Aythya fuligula		18.00	3.50	5.00	4.50
Aythya marila		20.00	3.50	6.00	5.00
Aythya nyroca		15.50	3.50	4.50	3.50
Bucephala clangula		21.00	4.50	5.50	4.00
Clangula hyemalis		19.50	4.50	7.00	4.50
Melanitta nigra		24.00	4.00	6.00	5.00
Mergus albellus	*Mergellus*	18.00	3.50	5.00	5.00
Mergus merganser		25.00	4.00	7.00	6.50
Mergus serrator		20.50	4.00	5.50	5.00
Somateria mollissima		29.00	6.50	10.00	7.00
Gruiformes					
Anthropoides virgo	*Grus*	42.50	7.50	17.00	11.00
Grus grus		51.00	11.00	13.00	10.00
Otis tarda		56.00	10.00	15.00	13.00
Otis tetrax	*Tetrax*	20.00	4.20	6.00	6.00
Ralliformes					
Crex crex		9.50	2.50	3.50	3.00
Fulica atra		18.00	4.00	5.50	5.00
Gallinula chloropus		12.50	3.20	4.00	3.00
Porzana parva	*Zapornia*	6.00	1.50	2.00	2.50
Porzana porzana		8.00	2.50	3.00	2.50
Rallus aquaticus		8.50	2.50	3.50	2.50

Species	New genus name	A	C	E	F
Charadriiformes					
Uria aalge		20.00	4.00	6.00	6.50
Glareola pratincola		15.20	3.00	4.50	5.00
Arenaria interpres		12.20	2.00	4.00	3.50
Calidris alpina		9.00	2.20	2.70	2.30
Charadrius alexandrinus		8.00	3.00	3.50	3.50
Gallinago gallinago		13.50	2.30	3.80	3.00
Himantopus himantopus		17.00	3.00	5.00	4.80
Limosa limosa		15.50	3.80	5.00	3.50
Lymnocryptes minimus		8.00	2.00	2.70	2.00
Numenius arquata		26.50	5.00	8.00	5.00
Philomachus pugnax		15.00	3.00	5.00	4.50
Pluvialis squatarola		17.00	4.00	5.20	5.00
Recurvirostra avosetta		20.00	4.00	6.20	5.00
Scolopax rusticola		19.50	3.00	6.00	4.50
Tringa erythropus		21.20	2.50	3.60	3.00
Tringa hypoleucos		8.80	1.70	2.50	2.00
Tringa nebularia		26.50	4.00	5.30	5.00
Tringa totanus		13.00	2.80	4.50	3.00
Vanellus vanellus		16.00	3.50	5.20	4.00
Chlidonias niger		17.50	3.50	5.50	3.00
Larus canus		28.00	6.50	7.50	7.50
Larus minutus	*Hidrocoloeus*	8.30	2.00	3.00	3.00
Larus ridibundus	*Chroicocephalus*	24.00	5.00	8.50	5.50
Stercorarius pomarinus		32.00	6.00	8.00	5.00
Sterna hirundo		22.00	4.00	6.50	5.50
Galliformes					
Alectoris graeca		12.50	4.00	5.20	3.50
Coturnix coturnix		7.50	2.00	3.20	2.80
Gallus domesticus		15.00	5.00	7.50	5.50
Perdix perdix		11.50	3.50	5.50	4.50
Lagopus lagopus		15.50	4.50	7.50	5.50
Lagopus mutus	*L. mute*	15.50	4.50	6.00	4.50
Tetrao tetrix		20-00	6.00	11.00	6.00
Tetrao urogallus		32.00	12.50	14.00	10.50
Tetrastes bonasia		21.00	6.00	8.50	6.20

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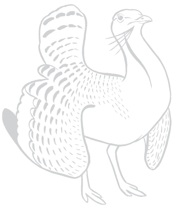

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The effect of Natura 2000 network on the Eurasian Eagle-owl *(Bubo bubo)* population in Southeast Bulgaria: implications for conservation

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Abstract The effectiveness and efficiency of the Natura 2000 network for the Eurasian Eagle-owl conservation in SE Bulgaria was assessed by comparing data collected during a long-term study on number of breeding pairs and fledglings before and after network establishment. The Natura 2000 network and non-protected areas showed similar values of the calculated indices according to the number of occupied localities. However, the pairs in Natura 2000 sites bred significantly less fledglings after the creation of the network than the pairs in non-protected ones. The Special Protection Areas (SPA) system created specifically for the preservation of birds has the lowest efficiency in respect to Eurasian Eagle-owl protection. Proposals were made after 'gap analysis' for real protection and optimization of the protected-area network to increase the stability of the Eurasian Eagle-owl population in the changing environment.

Keywords: conservation goals, conservation effectiveness, top predator, Special Protection Areas, Special Areas of Conservation

Összefoglalás Délkelet-Bulgária területén hosszú távú vizsgálat alapján elemeztük a Natura 2000 hálózat hatékonyságát és eredményességét az uhu konzervációbiológiájában, amelyhez számos, a hálózat kijelölése előtti és utáni időszakban gyűjtött költőpár és fióka adatait használtuk fel. A Natura 2000-es hálózat és a nem védett területek esetén az elfoglalt területek száma szerint számított mutatók hasonlóak voltak. A Natura 2000-es területeken költő párok a hálózat kijelölése után azonban szignifikánsan kevesebb kirepült fiókát neveltek fel, mint a nem védett területeken fészkelő párok. A kifejezetten a madarak megőrzésére létrehozott SPA rendszer az uhu védelmét tekintve a legkevésbé hatékony. A gap-elemzést követően javaslatot tettünk a védelem hatékonyságának javítására és a védett területek hálózatának optimalizálására annak érdekében, hogy növeljük az uhu populáció stabilitását a változó környezetben.

Kulcsszavak: konzervációs célok, konzerváció hatékonyság, csúcsragadozó, különleges madárvédelmi terület, különleges természetmegőrzési terület

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Introduction

The preservation and sustainable use of wildlife in protected areas are among the largely used global practices (Margules & Pressey 2000, Watson *et al.* 2014, Geldmann *et al.* 2019). The EU's Natura 2000 network is the largest system in the world covering one-fifth of the union land area (European Commission 2021). Its main target is to preserve biodiversity of the continent in the process of accelerated economic development (Trochet & Schmeller 2013, Gantioler *et al.* 2014). Bulgaria designated its Natura 2000 network in time of the accession to EU in 2007 and nowadays it covers 34.9% of the territory of the country. Both groups of sites in the network namely Special Protection Areas (SPA) with 23.1% and Special Areas of Conservation (SAC) with 30.3% designated, respectively, under the EU Birds Directive and the EU Habitats Directive, largely overlap (website of the Ministry of Environment and Water 2021). The existing National Protected Areas network (NPA) as parks and reserves, and smaller protected areas designated according to the national Protected Areas Act served as base for development of Natura 2000 in Bulgaria and most of them were included in SPAs and SACs. The change of the Nature protection legislation in 2002 followed by the creation of national Natura 2000 network in 2007 intend to maintain and restore the conservation status of priority habitats and species.

Top predators are keystones in the conservation strategy as an integral part of biodiversity and their great importance for ecological community dynamics (Sergio *et al.* 2006, 2008, Regos *et al.* 2017). They are usual flagships to promote nature protection, and important for the economic benefits of local communities from nature-friendly management of protected areas (Burgas *et al.* 2014, di Minin & Moilanen 2014). The Eurasian Eagle-owl *(Bubo bubo)* is the largest and strongest nocturnal avian predator, the least concern and increasing European population of which has an unfavorable conservation status in the continent (BirdLife International 2017). The Bulgarian population is stable estimated to 450–550 pairs but depleted from a decline suffered during the last century (BirdLife International 2017). The National Red Data Book included the Eurasian Eagle-owl as an endangered species (Golemanski 2015). The Eurasian Eagle-owl is listed in Annex I of the EU Birds Directive and requires designation of SPAs in Natura 2000 network. Therefore, the status of its population before and after the creation of the national Natura 2000 network is indicative of the effectiveness of the protection-area systems.

The present study assesses the role of the protected-area system with respect to the Eurasian Eagle-owl population in SE Bulgaria through: i) determining the effectiveness and efficiency of the three systems of protected areas according to the breeding distribution; ii) specifying the fledgling effectiveness and fledgling efficiency of the protected-area systems based on the fledgling production. We expect SPAs to be the most effective protected-area system as they have been declared specifically for preservation of birds. We expect the breeding pairs in protected-area systems to produce significantly more fledglings after establishment of the Natura 2000 network in comparison to those in non-protected areas.

Material and Methods

The study covered an area of about 10,000 km^2 in southeastern Bulgaria, 9% of the country (42º 22' 00" N 27º 00' 00" E) *(Figure 1)*. The predominant relief is hilly and flat with arable lands, pastures, oasis and riparian deciduous forests with mainly a continental Mediterranean climate (see also Milchev *et al*. 2019). Several low mountains and hills with a height usually up to 300–400 m a.s.l. are located in the southern part near the border with Turkey. Deciduous forests with predominance of oaks (*Quercus* sp.) cover this border area. The forest area decreases from east to west, being replaced by arable land and pastures on flattened ridges and gradual slopes. The depopulation of villages and small towns has been an ongoing process in the region, especially since 1990 due to political changes. The Black Sea coast is much less affected by depopulation because of coastal resort development and tourism growth. The three protected-area systems cover 47.9% of the study area (marine waters are excluded as they are not a habitat of the Eurasian Eagle-owl) *(Figure 1)*. The protected-area network includes mainly the southern state border area and the Black Sea coast.

The Eurasian Eagle-owl is a rock-nesting species in the area and its distribution depends on the available rock complexes with possibility of undisturbed breeding (Milchev *et al*. 2019). The diet is very diverse and with significant temporal changes in the dominant structure both in individual territories (Milchev 2016, Milchev & Spassov 2017) and at the population level (Milchev & Georgiev 2020). Data for breeding distribution and output were collected during the period 2000–2013 and included a 7-year interval before and after the establishment of Natura 2000 network (Milchev *et al*. 2019). This long-term study avoids possibility of misjudgment due to incomplete or short-term occurence of data. Comparisons between the protected and non-protected areas were based on:

(1) number of occupied breeding localities: the least evidences of an occupied rocky complex by Eurasian Eagle-owls were their excrements and food remains;

(2) number of fledglings that reached the age of 45–50 days. Older fledglings are hard to find because they tend to stray from the nest (Penteriani & Delgado 2019);

(3) fledglings rate: number of fledglings per successful pair.

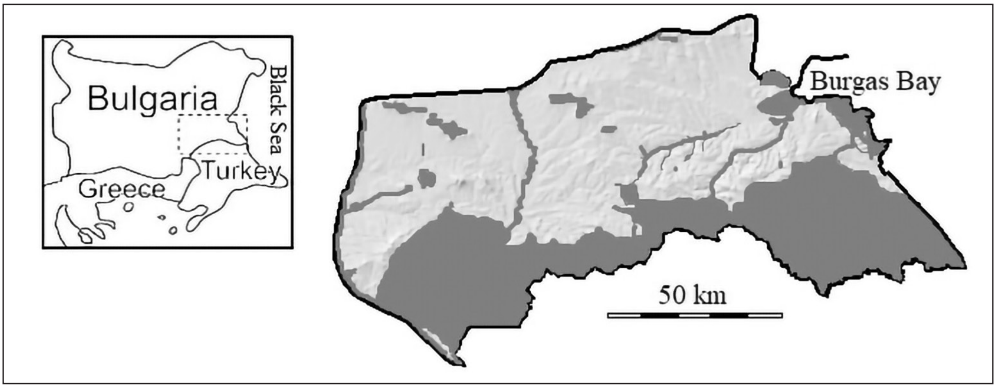

Figure 1. Study area in SE Bulgaria with marked protected-area network
1. ábra A mintavételi terület Délkelet-Bulgáriában, jelölve a védett területek hálózatát

The indices of effectiveness, efficiency (Abellán *et al*. 2011), fledgling effectiveness and fledgling efficiency of the three protected-area systems and their combined importance for the breeding popuation of the Earasian Eagle-owl in SE Bulgaria were computed:

(a) Effectiveness index, defined as the proportion of breeding localities included within the system s: Effectiveness = Ns/N, where Ns is the number of localities protected by system s, and N is the total number of localities.

(b) Efficiency index, defined as the proportion of breeding localities included within the system s in relation to the surface of the system: Efficiency = Ns/(N*As), where As is the proportion of land surface of the study area protected by the system s.

(c) Fledgling effectiveness index, defined as the proportion of fledglings of Eurasian Eagle-owl bred within the system s: Fledgling effectiveness = Fs/F, where Fs is the number of fledglings bred within the system s, and F is the total number of fledglings.

(d) Fledgling efficiency index, defined as the proportion of fledglings bred within the system s in relation to the surface of the system: Fledgling efficiency = Fs/(F*As).

Differences between the numbers of occupied breeding territories and fledglings in protected and non-protected areas before and after establishment of Natura 2000 network were calculated with a chi-square test applying Yates' correction. The significance level was $P<0.05$.

Results

The number of occupied breeding territories of Eurasian Eagle-owls increased slightly in both protected and non-protected areas after formation of Natura 2000 network in 2007 and the change was insignificant ($\chi^2=0.0003$, $df=1$, $P>0.05$) *(Table 1)*. The effectiveness index of the total protected-area network did not exceed the index for the non-protected area *(Table 1)*. SACs were the most effective system with 95% of protected localities included (n=21 localities). There was a cumulative effect of the three protected-area systems, which

Table 1. Effectiveness and efficiency of the protected area network in SE Bulgaria for the protection of the local Eurasian Eagle-owl *(Bubo bubo)* population

1. táblázat Délkelet-Bulgária ökológiai hálózatainak eredményessége és hatékonysága a lokális uhu *(Bubo bubo)* populáció védelmében

Area	**Occupied localities**		**Area km^2**	**As**	**Effectiveness**	**Efficiency**
	before 2007	**since 2007**				
NPA	11 (30.6%)	9 (21.4%)	1238.9	0.12	0.21	1.79
SPA	13 (36.1%)	12 (28.6%)	3683.0	0.37	0.29	0.77
SAC	19 (52.8%)	20 (47.6%)	4142.5	0.41	0.48	1.15
Protected combined	19 (52.8%)	21 (50.0%)	4789.2	0.48	0.50	1.04
Non-protected	17 (47.2%)	21 (50.0%)	5210.8	0.52	0.50	0.96
TOTAL	36	42	10000			

Table 2. Breeding performances, fledgling effectiveness and efficiency indices of the Eurasian Eagle-owl *(Bubo bubo)* population in SE Bulgaria before and after establishment ot Natura 2000 network in 2007

2. táblázat Az uhu *(Bubo bubo)* populáció szaporodási teljesítménye, a kirepülés eredményességi és hatékonysági indexe Délkelet-Bulgáriában a Natura 2000 hálózat 2007-es kialakítása előtt és után

Area	Fledglings		Fledgling rate		Fledgling effectiveness	Fledgling efficiency
	before 2007	since 2007	before 2007	since 2007		
NPA	41 (25.9%)	26 (15.0%)	2.2	1.7	0.15	1.25
SPA	48 (30.4%)	46 (26.6%)	2.1	1.8	0.27	0.72
SAC	76 (48.1%)	56 (32.4%)	2.1	1.9	0.32	0.79
Protected combined	76 (48.1%)	62 (35.8%)	2.1	1.9	0.36	0.75
Non-protected	82 (51.9%)	111 (64.2%)	2.0	1.8	0.64	1.23
Total	158	173	2.1	1.8		

alone are less effective. However, it did not apply to the network efficiency. NPAs were the most efficient system in comparison to SPAs, which proved to be the least efficient system for the target species.

There was a significant association between raised fledglings and particular protected status of the breeding localities (χ^2=4.62*, df*=1*, P*<0.05). Young Eurasian Eagle-owls fledged less frequently in the Natura 2000 network after its establishment *(Table 2)*. Pairs in the non-protected area raised 64.2% of all fledglings (n=173) for the same period. The fledgling rate of the population decreased from 2.1 to 1.8 fledglings after the establishment of the Natura 2000 network. The decrease affected the breeding pairs equally in both protected and non-protected areas.

The indices for fledgling effectiveness and fledgling efficiency of the protected-area network were about twice lower compared to their values for the non-protected area *(Table 2)*. The fledgling efficiency index in NPAs stood out with a very high value among the three protected-area systems and was the only one to reach the value of the index in non-protected areas. No cumulative effect was found in the value of the efficiency index from the superimposition of the three systems of protected areas.

Discussion

Protected-area networks are part of the natural environment and are subject to constant change mainly due to human activities, both positive and negative. The EU's Natura 2000 network is crucial for reducing losses in environmental and landscape diversity, with changes remaining greater in surrounding non-protected areas (Kubacka & Smaga 2019). Changes in SPAs and SACs have already been reported in Bulgaria (Nikolov *et al*. 2014), but without any alteration in the Eurasian Eagle-owl population and without taking into account the effectiveness of the protected area in comparison to the surrounding non-protected area. The effectiveness and efficiency of the protected-area network for Eurasian Eagle-owl population in SE Bulgaria proved to be similar to those of the non-protected area. SPAs must have been the most effective and efficient protected-area system for the species. However, the efficiency index placed NPAs as the most efficient among the three systems according to the land surface and number of localities of the target species. The reason for this is primarily that 5 localities (56%, n=9) have been included in the NPA system at the author's suggestions to protect areas with high biodiversity and breeding localities of threatened birds (Milchev & Georgiev 2014).

Differences in individual productivity among the population of territorial predators have long been known (Newton 1979). The qualities of the breeding territory and nesting site such as food supply, protection from human activities, enemies and competitors, climatic factors, but probably also the individual abilities of the territory owners are driving differences in the productivity among Eurasian Eagle-owl populations (Penteriani & Delgado 2019). Therefore, reproductive output allows to assess whether the protected areas have included the more productive part of the population. Thus, investments in the creation and management of the Natura 2000 network meant to ensure the sustainable state of the Eurasian Eagle-owl population that inhabits them (León-Ortega *et al.* 2017). The more productive part of the population in the protected network could support the population outside the protected areas, which is expected to suffer from more diverse and intensive negative human influences. The results demonstrated just the opposite in SE Bulgaria. The breeding pairs in the Natura 2000 network produced significantly less fledglings after the establishment of the network, while the fledgling rate decreased synchronously in protected and non-protected areas. One reason is that the three protected-area systems did not have actual ranger protection to reduce the primary breeding losses in the study area from destroyed or disturbed nests by people (Milchev *et al*. 2019).

Food supply in the hunting territory usually defines the reproductive output of the Eurasian Eagle-owl (Penteriani & Delgado 2019, Scherzinger & Mebs 2020). The significant increase of superpredation (hunting predatory mammals and birds) in the diet of the study population (Milchev & Georgiev 2020) was an indicator of deteriorating food supply and food stress (Penteriani & Delgado 2019). Reduced fledgling rate of the population corresponded to this pattern in the dietary structure. The Natura 2000 network mainly covers the area along the border with Turkey, which is most affected by depopulation, the decline of livestock, and the abandonment of arable land (Milchev & Georgiev 2020). The diet of the pairs there (see *Clusters 1, 3, 6, 7, Figure 4* in Milchev & Georgiev 2020) included the highest values of superpredation and otherwise rare atypical prey such as many smaller species of open and wood-shrubby habitats after the establishment of the Natura 2000 network. The combined impact of the crucial negative factors leading to breeding losses and poor food supply explain the low efficiency of the Natura 2000 network in the region and the resulting lack of sustainable perspective for the Eurasian Eagle-owl population in SE Bulgaria. A similar combination of factors explained the extinction of Egyptian Vultures *(Neophron percnopterus)* (Milchev & Georgiev 2014) from the region and the local decline of Lesser Spotted Eagles *(Clanga pomarina)* (Demerdzhiev *et al*. 2019).

Implications for conservation

Investments in the creation and management of the Natura 2000 network must ensure the sustainable development of the Eurasian Eagle-owl population. The poor and incommensurate effectiveness and efficiency of the protected-area network indicate the need for urgent changes in several directions after 'gap analysis' (Scott & Schipper 2006).

1) Management gaps:

The NPA system does not provide security for breeding pairs due to the lack of legal and financial capacity for effective protection with rangers. Adequate management and security of the NPA system will improve the productivity of all species sensitive to or benefiting from human presence. These measures will boost the efficiency of the Natura 2000 network, which includes the vast majority of the NPA system.

Breeding pairs in rocky quarries produced similar number of fledglings like in natural rocky complexes (Milchev *et al.* 2019). Environmentally-friendly management in quarries at list in the Natura 2000 network will minimise the breeding losses of the Eurasian Eagle-owl and other threatened bird species nesting there (Milchev *et al.* 2019, Rohrer *et al.* 2020).

2) Ecological gaps:

The protected-area network must be developed and take into account the current data on the status of the target species and habitats. Ecological gaps in the Natura 2000 network with inadequate protection of the rodents Roach's Mouse-tailed Dormouse *(Myomimus roachi)* and Romanian Hamster *(Mesocricetus newtoni)* (Milchev & Georgiev 2012) proved to be very similar to those of the Eurasian Eagle-owl in SE Bulgaria. Only the first rodent species was subsequently removed from the lists of priority species in these SACs, which Milchev and Georgiev (2012) cited as an example of species included in protected areas without proven localities. The protection of both mammals remains unresolved in SE Bulgaria, despite the conclusion of Nedyalkov *et al.* (2018) for adequate habitat presence in the Natura 2000. Apparently, none of the rodent species prefer the protected areas designated for them as it is now the case with Eurasian Eagle-owl. Therefore, given the large area of the Natura 2000 network in Bulgaria, we support the recommendation of Gantioler *et al.* (2014) for optimizing the protected-area network in the member states where its area is well above the EU average. Much better effectiveness and efficiency of the Natura 2000 network for the Eurasian Eagle-owl and other species from the Bird and Habitat Directives will be achieved if the network includes the already preferred parts of SE Bulgaria by the species themselves according to the studies of Milchev and Georgiev (2012), Milchev and Menzel (2017), Chobanov and Milchev (2020).

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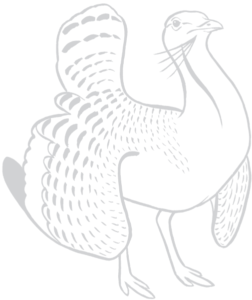

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Long-term lead intoxication of Griffon Vulture (*Gyps fulvus* Hablizl, 1783) supposedly the result of illegal shooting

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Abstract The European Griffon Vulture *Gyps fulvus* is a large-sized scavenger exploiting carcasses of livestock and wild ungulates and thus having a paramount importance in the natural ecosystems. In this study, we report on an adult Griffon Vulture detected with lead levels in the bones over the threshold. After two years of tracking, the bird died. The corpse's clinical examination and radiography detected the presence of two embedded lead pellets from a healed gunshot wound in its right wing. Quantitative laboratory analysis of lead in bone and liver samples evidencing subclinical/chronic lead intoxication of the Griffon Vulture could potentially be a result of the long-term exposure to the lead originating from the pellets in its wing.

Keywords: scavenger, toxicity, heavy metal, Eastern Rhodopes, embedded lead pellets

Összefoglalás A fakó keselyű *(Gyps fulvus)* egy nagytestű, dögevő ragadozómadár-faj, amely haszon- és vadállatok elhullott tetemein táplálkozik és ezáltal fontos szerepet tölt be a természetes ökoszisztémában. Ebben a tanulmányban egy olyan öreg példány elhullásáról számolunk be, amelynek véréből már egy korábbi mintavétel során is határértéken felüli ólomkoncentráció mutatkozott. A műholdas jeladóval ellátott egyed két évvel később elpusztulva került meg. A tetem boncolását és röntgenvizsgálatát követően bebizonyosodott, hogy a madár jobb szárnyában két, korábbi lövésből származó ólomsörét volt beágyazódva. A laborvizsgálatok során a fakó keselyű csontszövetéből és májából származó minták egyaránt szubklinikai/krónikus ólommérgezésre utaló koncentrációt mutattak, amelyet feltehetően a madár szárnyában hosszú ideig jelenlévő sörétszemek okoztak.

Kulcsszavak: dögevők, toxicitás, nehézfémek, Kelet-Rodope, beágyazódott ólomsörét

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Introduction

The Eurasian Griffon Vulture *Gyps fulvus* is a large Old World vulture that scavenges carcasses of livestock and wild ungulates (DeVault *et al.* 2003). Its breeding distribution extends from Kazakhstan and Nepal in the east, throughout the Caucasus, southern Europe and the Iberian Peninsula to the west (BirdLife International 2020). Adult Griffon Vultures are mostly resident, while juveniles are primarily nomadic, some exhibiting migratory behaviour, overwintering in Africa and the Middle East (del Hoyo *et al.* 1994, McGrady & Gavashelishvili 2006, Arkumarev *et al.* 2019). On the Balkan Peninsula, the species breeds in Bulgaria, Greece, North Macedonia, Serbia and Croatia (Sušić 2004, Xirouchakis & Tsiakiris 2009, Grubač 2013, Sušić & Radek 2013, Velevski *et al.* 2013, Demerdzhiev *et al.* 2014). The Griffon Vulture population in Bulgaria has steadily increased in the past 30 years as a result of intensive conservation actions and reintroduction programmes (Dobrev & Stoychev 2013, Demerdzhiev *et al.* 2014, Stoynov *et al.* 2018).

Lead is a highly toxic heavy metal with an important impact on bird populations. Absorption of a low concentration of lead may result in a wide range of sublethal effects in animals, and higher concentrations may result in acute intoxication and consequent death. It is an accumulative metabolic poison that is non-specific, affecting a wide range of physiological and biochemical systems including the hematopoietic, vascular, nervous, renal, immune and reproductive systems (Franson & Pain 2011, Pain *et al.* 2019).

Lead poisoning originating from ammunitions is a well-known threat for wildlife species on a global scale (Plaza *et al.* 2018, Pain *et al.* 2019). Evidence of lead intoxication negatively affecting raptor species are documented for many endangered birds such as the Californian Condor *Gymnogyps californianus*, the Cinereous Vulture *Aegypius monachus*, the Egyptian Vulture *Neophron percnopterus* on the Balkans and the Bearded Vulture *Gypaetus barbatus* in North America, Spain and the Alps (Fry 2003, Rodriguez-Ramos *et al.* 2008, Bounas *et al*. 2016, Ganz *et al.* 2018).

Several mechanisms of lead intoxication are reported in wild birds. Lead from ammunitions dispersed in the environment can be swallowed (Beintema 2001, Scheuhammer *et al.* 2003), and/or embedded within the bird`s tissues after shooting and consequently, accumulated in the blood over time (Finkelstein *et al.* 2014, LaDouceur *et al.* 2015).

Griffon Vultures feed on various game species found in the landscape, which puts them at high risk of chronic or acute lead poisoning by ingesting lead pellets embedded in tissues of the shot animals (Carneiro *et al.* 2016, Arrondo *et al.* 2020). Juvenile and immature vultures spend their first years of life wandering vast areas in the Middle East, Africa and Asia (Arkumarev *et al.* 2019) and can become victims of illegal shooting. Some wounded birds survive and continue their way south carrying lead pellets embedded in their tissues. Illegal killing is among the main threats and of great conservation concern in the Eastern Mediterranean countries where annually thousands of raptors and other migratory birds are shot on their way to Africa (Brochet *et al.* 2019). Demerdzhiev *et al.* (2014) reports 15.79% of the Griffon Vultures found dead in Bulgaria from 1979 to 2011 as victims of illegal shooting. However, this threat is considered to bear a low impact on the Griffon Vulture globally (Botha *et al.* 2017), but yet, there are numerous cases of killed or injured vultures.

The lead intoxication of Griffon Vulture in various aspects is well studied in Spain (García-Fernández *et al.* 2005, Espín *et al.* 2014, González *et al.* 2017, Arrondo *et al.* 2020). However, the impact and evidence of this threat have not been reported from the Balkans. We present here a case of long-term chronic lead intoxication of a wild Griffon Vulture, tracked with a GPS transmitter and found dead in the Eastern Rhodopes, Bulgaria.

Materials and methods

The Griffon Vulture was captured on 25.05.2017 via a walk-in trap in the Eastern Rhodopes, Bulgaria. Based on its plumage, the vulture was aged as an adult (Forsman 2003). Based on a blood DNA sample, the vulture was sexed as a female. The bird was measured at the time of trapping obtaining weight and morphometrics. The vulture was marked with a colour wing tag, a standard metal ring, and a colour ring, to ease its identification in the wild. Blood and saliva samples were collected for toxicological and microbiological analysis. The Griffon Vulture was also fitted with a solar-powered 57g GSM/GPS and accelerometry transmitter (E-Obs GmbH; 132 Munich, Germany) attached as a backpack configuration with 11.2 mm Teflon ribbon (Arkumarev 2020).

The vulture died on 17.04.2019 in the Eastern Rhodopes, Bulgaria. The body was recovered on the next day in good overall condition. The bird was transported for admission to the Wildlife Rehabilitation and Breeding Centre "Green Balkans" – Stara Zagora (WRBC), where initial external examination and body weight measurement were conducted. A consequent radiography was assigned. A standard gross pathological examination followed. The necropsy was executed to investigate the reasons that led to its death. Sample from femur bone and liver to test for lead (Pb) contents were obtained additionally and sent for quantitative lead tests to an accredited laboratory in Bulgaria.

Results

The Griffon Vulture was tracked for 692 days in 2017–2019. This period covers partially or entirely three breeding seasons (2017, 2018, 2019). During this period, no successful breeding was recorded by either telemetry data or by visual observations.

The concentration of Pb in the blood of the bird taken during the tagging was 384.85 ng/g (0.385 mg/kg) dry weight (dw). The vulture weighed 7.6 kg. At the time of admission at WRBC, the corpse of the bird weighed 5.880 kg. During the gross external examination, no clues for electrocution, collision, acute poisoning or poaching were recognized.

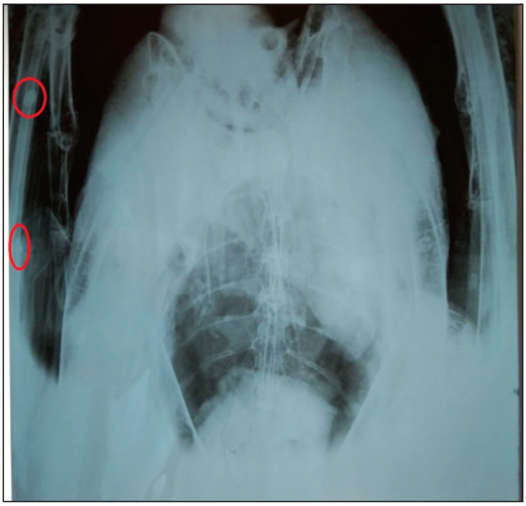

Figure 1. Ventrodorsal X-ray image of the Griffon Vulture with two lead pellets in the right wing

1. ábra A fakó keselyű ventrodorzális nézeti röntgenfelvételén jól kivehető a jobb szárnyban lévő két sörétszem

The radiography detected two foreign metal particles in the bone of the right wing, supposed to be lead pellets *(Figure 1)*. No specific gross organ lesions were detected during necropsy, however, evidence for hepatic necrosis was observed. Visual inspection of the reproductive organs showed atrophy. Laboratory findings indicated the presence of lead in the analyzed femur and liver samples. The post mortem bone sample resulted in 11.58±1.16 mg/kg dw of Pb in the tissue. Lead levels in the liver tissue were 4.06±0.41 mg/kg dw.

Discussion

In this paper, we document a case of a Griffon Vulture from the Balkan population that was a victim of an illegal shooting and carried lead pellets inside its body. Usually, a period of at least two months is necessary for calcification of bones after injury (Paskalev 2013). The bird was tracked and closely monitored with a GPS transmitter for two years. During this period, abnormal behaviour was not observed, which might suggest that the vulture was shot or injured. This indicates that the pellets have been embedded in the bird`s right ulna for a long time. We suggest that the bird was already having the lead pellets calcified when it was captured and tagged as it had the highest Pb blood levels of all Griffon Vultures (n=33) we have tested (Escobar-Gonzales *et al.* 2020). The vulture weighted 7.6 kg during tagging that was reduced to 5.88 kg postmortem, which is considered abnormal weight for a female Griffon Vulture (normal weight between 8–11 kg (Carneiro *et al.* 2016).

Morphologically, liver lesions in birds were reported as a sign of lead intoxication by Ochiai *et al.* (1993) and Pikula *et al.* (2013). The observed dystrophic changes of the reproductive organs of the vulture suggested its inactivity through the last breeding season. We hypothesise that the vulture was not able to breed because it suffered a long-term lead intoxication which affected its overall health and fertility in compliance with the findings of Vallverdú-Coll *et al.* (2016).

We registered high levels of lead in the bones (11.58±1.16 mg/kg dw) of the vulture. Bone lead concentration is generally the best indicator of lead exposure over the lifetime of a bird (Franson & Pain 2011). Bone lead concentration higher than 10 mg/kg dry weight is considered as inflated and levels higher than 20 mg/kg are associated with clinical signs of acute lead intoxication (Mateo *et al.* 2003, Plaza & Lambertucci 2018).

We recorded Pb values of 4.06±0.41 mg/kg dry weight, equal to 1.31 ppm wet weight (ww) after conversion, in the liver, which appeared to be consistent with the findings of LaDouceur *et al.* (2015). The author reported these levels to correspond with subclinical elevations of hepatic lead in nine cases of dead wild birds with radiographically evident gunshot projectiles in the tissues (0.29–3.84 ppm ww).

The blood Pb concentration of the vulture at the time of tagging was 384.85 ng/g, equal to 0.38 ppm and corresponded with an earlier study of U.S. Fish & Wildlife Service (1990), which found that blood lead values starting from 0.2 ppm is a threshold when toxicity symptoms begin to appear.

However, blood and liver lead concentrations, in our case, were significantly lower than that reported for Griffon Vultures suffered of acute poisoning due to ingestion of lead pellets in another study (Carneiro *et al.* 2016). In cases of chronic exposure, the highest lead concentrations are found in bone with lower concentrations in soft tissues such as liver and blood (Franson & Pain 2011). We hypothesise that the Griffon Vulture in our study suffered a long-term chronical exposure to lead, possibly from the pellets found in its wing. Consequently, the shot was no life threatening, which allowed the bird to live long enough to accumulate lead over the threshold levels. A study of the diet of Griffon Vultures in the Eastern Rhodopes (Arkumarev *et al.* 2021) reports cause of mortality for 93 specimens used for food by the vultures, 4.3% of which were hunted or poached. Lead could also have accumulated over time as a result of ingestion of lead pellets with the food. However, blood samples from 32 other Griffon Vultures from the same population did not indicate elevated lead concentrations (Escobar-Gonzales *et al.* 2020).

Lead is a highly toxic heavy metal that acts as nonspecific poison affecting all body systems. Absorption of low concentrations may result in a wide range of sublethal effects on animals, and higher concentration may result in mortality (Franson & Pain 2011). Little is known about the origin of the lead pellets in our case, however, it is an evidence of poaching. Significant numbers of young Griffon Vultures from Eurasia migrate to the Middle East and Africa. A GPS tracked Griffon Vulture from the same colony in the Eastern Rhodopes, Bulgaria, has reached South Sudan in Africa (Arkumarev *et al.* 2019). There are estimates that at least 1.7–4.6 million birds of at least 413 species may be killed or taken illegally each year in the countries of the Middle East (Arabian Peninsula, Iran, Iraq) (Brochet *et al.* 2019). Consequently, the bird could have been shot somewhere in its wandering, overwintering or resident areas. That case stresses that lead poisoning in birds from ammunition occurs in different forms and may lead to physiological changes in the individual that affect its reproduction capacity and threaten its life.

That issue needs to be explored at a larger scale as it is currently unknown how many vultures are victims of such illegal practices. There is a need for further exploration of illegal shootings along the species' flyway and also in the residential areas in Bulgaria.

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Nesting and breeding attempts of *Cecropis daurica* (Laxmann, 1769) in Tunisia

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Abstract During fieldworks in 2019, a pair of Red-rumped Swallows *(Cecropis daurica)* were seen building their nest (June) and one of them brooding (August). The pair was still present in the area by the end of September, while all other swallows left this breeding area. In June 2020, the nest entrance was destroyed and the nest was occupied by a pair of *Passer* sp. Another nest of *C. daurica* was found in an abandoned building but was completely destroyed. This observation is the first record concerning an attempt and failure of nesting of the species in Tunisia. The nesting area of the Red-rumped Swallow is extended to the Mediterranean in southern Europe and to northwest Africa. The nesting sites are described, and the extension of the nesting area is discussed in this work.

Keywords: *Cecropis daurica*, nesting failure, Kroumiria, Tunisia

Összefoglalás Egy vörhenyes fecske *(Cecropis daurica)* pár fészeképítését (június) és költési kísérletét (augusztus) figyelték meg Tunéziában, 2019-ben. A pár egészen szeptember végéig maradt a területen, miközben más fecskék már elhagyták költőterületüket. 2020 júniusában a fészek bejárata már sérült volt, és valamely verébfaj (*Passer* sp.) foglalta el azt. Később egy elhagyatott épületben egy újabb vörhenyes fecske fészket találtak, de az sajnos teljesen megsemmisült. Ezek az első adatok a vörhenyes fecske tunéziai fészkelési kísérleteire, amelyek sajnos sikertelenek voltak. A faj fészkelőterülete Európában a Mediterráneumra, illetve Északnyugat-Afrikára terjed ki. Jelen tanulmányban a fészkelőhelyek leírásáról és az új területek lehetséges meghódításáról is értekezünk.

Kulcsszavak: vörhenyes fecske, költési kísérlet, elterjedés, Kroumiria, Tunézia

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Introduction

Bird diversity is relatively well known compared to the rest of the vertebrates of Tunisia (Isenmann *et al.* 2005). In the last decade, new species have been observed in the country (Azafzaf *et al.* 2015). Breeding species have also been added to the previously known lists (Ouni *et al.* 2009, Olioso *et al.* 2013).

However, some regions remain poorly studied, at least concerning their ornithological diversity, such as Central Tunisia (non-coastal) and Kroumiria. Indeed, studies made in the two regions are rare (see e.g. Touihri *et al.* 2015), and more or less continuous observations concern only particular habitats, mainly wetlands or those of having relatively easy access. It is also important to emphasize that observations during the breeding season of birds are not frequent, especially during the summer period.

Kroumiria, located in the northwestern part of Tunisia, is the most forested and humid region of the country (Posner 1988). The vast areas of forests are mainly composed of zeen oak *(Quercus canariensis)*, cork oak *(Q. suber)*, kermes oak *(Q. coccifera)* and maritime pine *(Pinus pinaster)*. It should be noted the presence of a small forest of *Quercus afares*, an Algero-tunisian endemic tree in Ain Zana. The umbrella pine *(P. pinea)* has been planted over large areas and tends to be natural in the region (Le Floc'h *et al.* 2010). Kroumiria contains many permanent or temporary wetlands (dams, hill lakes, rivers, wet meadows), as well as the only extended peat bog in Tunisia (Dar Fatma).

Five species of swallows are listed in Tunisia (Isenmann *et al.* 2005). Three of them are regularly breeding. These include the Eurasian Crag Martin *(Ptyonoprogne rupestris)*, the Barn Swallow *(Hirundo rustica)* and the Common House Martin *(Delichon urbicum)*. The other two species, the Sand Martin *(Riparia riparia)* and the Red-rumped Swallow *(Cecropis daurica)* are considered migratory passengers.

The Red-rumped Swallow has a large global distribution area, which covers South-Europe, Asia and Africa (Chişamera 2006). Around the Mediterranean, it breeds from the Iberian Peninsula east to Greece, the Balkans, Cyprus and the Middle East, as well as in Algeria and Morocco (Chişamera 2006, Wilson *et al.* 2006, Pilgrim & Tordoff 2010, Liu *et al.* 2014).

The main objective of this paper is to provide evidence of first nesting and failure of the Red-rumped Swallow in Tunisia, by describing its nesting sites and discussing its potential geographical extension in the country.

Materials and Methods

Study area

The sites where nests have been observed were located in a public plant nursery for the production of forest seedlings and an abandoned factory building located at around 2.5 km west of the nursery. The plant nursery is situated East of Tabarka city and is established on the edge of a forest on coastal dunes (Posner 1988). Original forest of kermes oak only persists on the coast. In the vicinity of the nursery, it has been replaced by pine trees (*Pinus pinea* and *P. pinaster*) and eucalyptus (*Eucalyptus* sp.). Some perennial meadows remain in the vicinity of the site, and are often grazed by livestock (sheep and cattle). More or less extensive wetlands persist in the area, but dry up in summer.

The abandoned factory is located at the edge of a pine forest *(P. pinea)* planted on fixed dunes, just in front of the route attending Tabarka airport. In this area, there were only two houses, but people from the neighbouring localities seem frequent the building, which doors and windows have been snatched by local people.

In both sites, the forest is dense, and the vegetation cover reaches 100% in the natural forests of kermes oak, but in the other types of forests, open spaces, often of small extension, persist. The plantations are several decades old and the trees often have a height exceeding 10 m. In planted forests, the undergrowth vegetation is almost absent, and unplanted areas are covered by scrubs, dominated by oleaster *(Olea europaea)* and Phoenician juniper *(Juniperus phoenicea)*. The soil is sandy.

The nursery is attended only by its staff, and the work during the dry season is reduced almost solely to the irrigation of seedlings. Disturbances are very small. The space reserved for the nursery is fenced and is not used by the surrounding populations. It is always guarded. The nursery has a water point that provides all its needs. It is linked to an aerial pool where water is stored for future use. Often, the pool overflows and pours water on the ground, forming a small permanent wetland where the Red-rumped Swallows were seen extracting the mud necessary for the construction of their nest (see below).

The abandoned factory is located near small wetlands and a river, dry in summer, but water stays in interspersed ponds along the watercourse. The substrate is sandy or loamy, and in these areas, the vegetation is specific to meadows (*Typha domingensis*, *Equisetum telmateia*, *Juncus* sp. etc.). Trees are specific to wetlands and river borders *(Alnus glutinosa, Fraxinus angustifolia, Nerium oleander, Vitis vinifera, Hedera algeriensis, Populus alba, Tamarix africana)*. Some other plant species are only localised and rare in the region *(Ulmus minor, Salix atrocinerea, Vitex agnus-castus)*. These wetlands are frequently grazed by herds of cows and wild boars.

In order to ensure an inventory and monitoring of the animal biodiversity of Kroumiria, regular fieldworks in the last two decades were carried out in various natural habitats of the region (pine and oaks forests, meadows, streams and wetlands).

Field visits were made mainly in the mornings, during the hot season (spring and summer), but they were made all day long otherwise. No night trips were made. Summer trips were reduced, because of heat, and were most often carried out to sites previously identified, to monitor particular species, including amphibians, reptiles or birds. In summer, the sites visited were mostly located at high altitudes, in undisturbed wetlands or in areas where certain species have been spotted at least once. Exploration trips of little known areas were also made but at much lower frequencies.

Result and Discussion

On the 14th of June, 2019, a routine visit to the nursery was done. Two unusual swallows were seen extracting mud from a small pond and dropping it a little further into an open shed. The two swallows were building a nest. They were photographed remotely during mud extraction in order to avoid their disturbance. The birds were later identified as Red-rumped Swallows.

Two months later, on the 16th of August, the site was revisited in the morning. The nest has been completed with its characteristic form and access tunnel. It was placed near the roof of an open shed used for the storage of nursery equipment, at a height of about 4 m. An individual entered and stayed there for at least 30 minutes, a sign that it was incubating eggs. This is probably the second brood. On the wall, there were only wasp nests. No other nest of swallows was present. The nest was not approached, so as not to disturb the bird.

Later, on the 27th of September, the pair of Red-rumped Swallow was still present. It was seen entering the nest for a short time, and then made many visits separated by short time intervals. No sound came from the nest. At this period, nesting swallows in the region left to their wintering areas. This delay of departure may be explained by the need to rear the last brood of the season. The absence of young at the entrance of the nest and chick calls could be explained by the fact that they were still too small.

In 2020, a visit was made to the nursery (on the 15th of June), but the swallow nest was found occupied with a pair of *Passer* sp., with its tunnel destroyed. This finding encouraged additional explorations in the vicinity of the nursery in order to look for the presence of possible other swallow nests and, on the 25th of June, a destroyed nest was found in front of an abandoned factory. It was at a height of about 3m, over its entrance. Occupation of Red-rumped Swallow nests by sparrows was also reported from India (Samson *et al.* 2017). All other explorations in the surroundings of the nursery were not successful.

In North Africa, the Red-rumped Swallow is known to breed in Morocco and Algeria (Heim de Balsac & Mayaud 1962, Etchecopar & Hue 1964, Isenmann & Moali 2000, Barreau & Bergier 2001, Bergier & Thévenot 2006). In Tunisia, the species is known only during migration (Thiollay 1977, Isenmann *et al.* 2005).

The nesting period of the Red-rumped Swallow in Tunisia seems to be late as the clutches are reported at the end of April in Morocco (Heim de Balsac & Mayaud 1962, Barreau & Bergier 2001) or in May (Etchécopar & Hüe 1964) and the spring migration in Tunisia is noted between mid-March and mid-May (Isenmann *et al.* 2005). Indeed, it is possible that the nest in the nursery was built after the destruction of the nest found last June. Around the Mediterranean, nesting is known between the months of April and September (de Lope 1980, Prodon 1982, Bazán 2007). Unlike its congeners, the Barn Swallow and the Common House Martin, the species nests individually or in small groups (Isenmann & Nicolau-Guillaumet 1992, Barreau & Bergier 2001).

The shape of the nest is very characteristic of the species, with its access tunnel and closed incubation chamber (de Lope 1980, Chişamera 2006, Bazán 2007). The location of the observed nest seems unusual for the species, known to build its nest in caves, cisterns, cave ceilings, rock clefts, and under bridges (Ferry 1961, Géroudet 1979, Prodon 1982, Vallée 1983, Chişamera 2006), although some authors report nesting in abandoned buildings (Fasola *et al.* 1997, Barreau & Bergier 2001). The Red-rumped Swallow has bred in a regular used underground car park in Hungary (Balatonfüred) (Bodor 2017). Potential nesting sites of the Red-rumped Swallow are not lacking in the region. Other nests may exist and stay unnoticed due to lack of exploration (Orta & Romero 1990, Moali & Isenmann 1991). The hypothesis of a second clutch is very likely. In fact, a second clutch is not rare for the species (Heim de Balsac & Mayaud 1962, de Lope 1980).

The presence of the species in Tunisia could be linked its expansion in the Mediterranean region (Isenmann & Nicolau-Guillaumet 1992, Sanz *et al.* 2015). The start of establishing nesting population from the actual birds and descendants is likely as long as fidelity to the nesting site is noted for this species (de Lope 1980). Therefore, the possible new nesting site was not found, and additional searches should be done in at least the neighbouring sites (bridges, dams, airport buildings).

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