

Occurrence of the great black hawk (*Buteogallus urubitinga*) in the largest urban area of South America

Výskyt myšiaka vodného (*Buteogallus urubitinga*) v najväčšej mestskej oblasti Južnej Ameriky

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Abstract: The great black hawk is widely distributed in South America, including Brazil and the state of São Paulo, but it is uncommon in the region of the city of São Paulo (Grande São Paulo), the largest urban area in South America. We compiled, organized, and analyzed available records of the species for this highly urbanized region in the literature, ornithological databases, and online birdwatching platforms, and produced field data. We obtained 13 records from four locations between 2018 and 2024. All records were associated with humid and flooded environments, mainly artificial reservoirs. The long period without records and the low number of recent detections suggest several possibilities: the species has always been uncommon in Grande São Paulo, perhaps for geographic, environmental, ecological, and/or climatic reasons; the species may be colonizing lakes and reservoirs created in recent decades; or the species is just a regional vagrant bird in Grande São Paulo. Nonetheless, the presence of this hawk in the surroundings of the largest urban area in South America shows the importance of the wetlands and floodplain remnants of the Alto Tietê Hydrographic Basin, which are threatened environments that urgently need protection by the establishment of conservation units.

Abstrakt: Myšiak vodný, je široko rozšírený druh Južnej Ameriky vrátane Brazílie a štátu São Paulo. V oblasti mesta São Paulo (nazývaného Veľké São Paulo), najväčšej mestskej oblasti Južnej Ameriky, je však tento druh zriedkavý. V práci sme zozbierali, spracovali a analyzovali dostupné literárne údaje, údaje z ornitologických databáz a online platforiem o sledovanom druhu v tomto vysoko urbanizovanom regióne. Získali sme 13 záznamov zo štyroch lokalít v rokoch 2018 až 2024. Všetky záznamy boli spojené s vlhkým a zaplaveným prostredím, najmä s umelými vodnými plochami. Dlhé obdobie bez záznamov a nízky počet nedávnych zistení naznačuje niekoľko možností: z možných geografických, environmentálnych, ekologických a/alebo klimatických dôvodov bol druh v sledovanom území vždy zriedkavý; druh môže kolonizovať jazerá a vodné plochy vytvorené v posledných desaťročiach; alebo sa druh v oblasti Veľkého São Paulo vyskytuje len eraticky. Napriek tomu prítomnosť myšiaka vodného v okolí najväčšej mestskej oblasti v Južnej Amerike poukazuje na význam mokradí a zvyškov záplavových oblastí v hydrografickom nížine Alto Tietê, ktoré predstavujú ohrozené prostredie a naliehavo vyžaduje ochranu prostredníctvom zriadenia chránených území.

Key words: Brazil, Atlantic Forest, city of São Paulo, field inventory, conservation

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Introduction

The great black hawk (*Buteogallus urubitinga*) occurs exclusively on the American continent, in Central and South America, from Mexico to Argentina and throughout Brazil (Sick 1997, van Dort 2020). It lives in open and semi-open humid natural areas, including swamps, mangroves, wetlands and riverine forests, but can also occur in anthropized areas, such as rice fields, flooded pastures and wetlands near oil refineries (Olmos and Silva e Silva 2003, Pallinger and Menq 2021). It has been recorded in large urban areas of Brazil and Argentina, among other regions, where they were considered unusual, a type of occurrence that is still little known for most of its geographic distribution (Sick and Pabst 1968, Maciel 2009, Pallinger and Menq 2021, Leveau et al. 2022).

It feeds mainly on small vertebrates (rodents, birds, lizards, snakes, fish, amphibians), as well as arthropods, the pulp of some fruits, and dead animals (Sick 1997, da Frota et al. 2021, Pallinger and Menq 2021). It has the behaviour of expelling some birds from their nest, such as the plumbeous ibis (*Theristicus caerulescens*), to prey on their eggs (Olmos 1990) and of capturing chicks that have fallen to the ground from heron and spoonbill nests (Sick 1997). Its nest is a platform of twigs and dry branches built high in trees, including palms, and almost always near rivers, lakes or swamps (Pallinger and Menq 2021). The reproductive period generally extends from June to May (van Dort 2020). In Minas Gerais, Southeast Brazil, nest construction was described as beginning between August and September, with incubation between September and October and chick development between November and December (Carvalho Filho et al. 2006). In Argentina, there are reports that these hawks build nests on artificial structures, such as telephone and high-tension poles (Olrog 1985).

In the state of São Paulo, Southeast Brazil, the great black hawk is found both on the coast, where it inhabits estuaries and mangroves, and inland, mainly along the largest rivers and lakes (Willis and Oniki 2003). It is uncommon in the Metropolitan Region of São Paulo (called throughout the text of Grande São Paulo), located between the coast and the interior of the state,

which is considered the largest urban area in South America with more than 20 million inhabitants (IBGE 2023). Historical records of individuals were collected in Grande São Paulo in 1934 and 1935 (Pinto 1938, Willis and Oniki 2003).

Urban areas are expanding worldwide, and there is a need to understand how this human alteration affects biodiversity. Therefore, every day, new studies are investigating the presence, resilience, extinctions and impacts of urbanization on biodiversity worldwide, a topic that needs to be expanded and encouraged (Li et al. 2022). Given this scenario, we reviewed historical and current records of the great black hawk in Grande São Paulo and evaluated its occurrence status in this largest urban area in South America.

Material and Methods

Study area

The study area covers the Grande São Paulo, which encompasses 7,944 km² in the eastern part of the state of São Paulo, Southeast Brazil (Fig. 1). Covering 39 municipalities and with around 22 million inhabitants, it is the largest urban area in South America (EMPLASA 2022, IBGE 2023). Grande São Paulo has several water reservoirs of various sizes that make up the Alto Tietê watershed system (e.g., Billings, Guarapiranga), a very important water supply for the population. The region is part of the Atlantic Forest domain and is surrounded by native forests, forming a green belt that is part of the Atlantic Forest Biosphere Reserve (Costa 1997). The Southeastern and southern limits of Grande São Paulo are located at the top of the Serra do Mar (a slope of the plateau facing the Atlantic Ocean) and are parallel to the coast, with an average altitude of 800 m (Fig. 1). The climate is humid subtropical or warm temperate, and temperatures vary between 0°C in winter and above 27°C in summer (Alvares et al. 2013). Grande São Paulo receives many cold fronts, which are stronger during the austral winter, and sea breezes due to altitudes above 700 m and proximity to the ocean (Morais et al. 2010).

Secondary data

Records were gathered from scientific articles, books, and

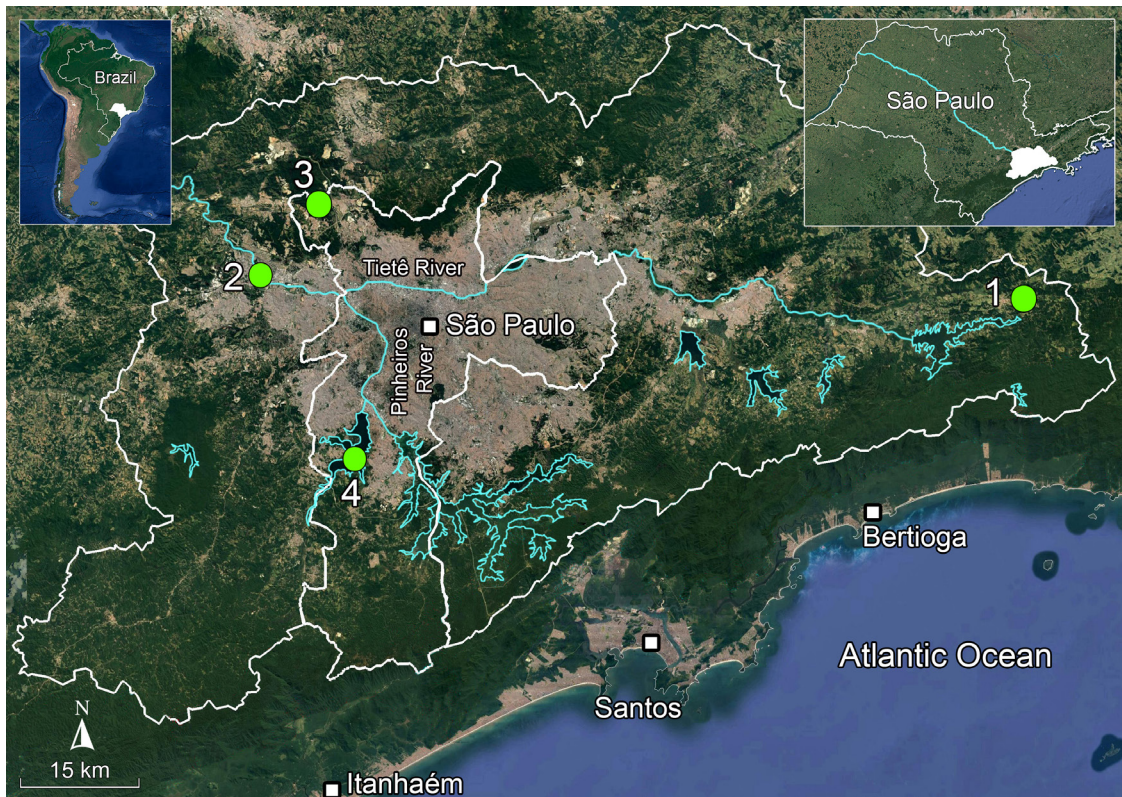


Fig. 1. Map of records for great black hawk (*Buteogallus urubitinga*) in the Metropolitan Region of São Paulo in Brazil. The white area on the map of South America indicates the state of São Paulo, and that on the map of the state of São Paulo indicates the Grande São Paulo, with the Tietê River crossing the state. The white polygon within the limits of Grande São Paulo indicates the municipality of São Paulo. The polygons outlined in blue indicate medium and large water reservoirs. The two main rivers that cross the Grande São Paulo are Tietê and Pinheiros. Green circles indicate locations with recent records documented by photography and vocalization recording. Satellite images were taken from Landsat/Copernicus 2015.

Obr. 1. Mapa záznamov myšiaka vodného (*Buteogallus urubitinga*) v metropolitnej oblasti São Paulo v Brazílii. Biela plocha na mape Južnej Ameriky označuje štát São Paulo a biela plocha na mape štátu São Paulo označuje Veľké São Paulo, ktorým preteká rieka Tietê. Biely polygón v hraniciach Veľkého São Paulo označuje mesto São Paulo. Polygóny vyznačené modrou farbou označujú stredné a veľké vodné plochy. Dve hlavné rieky, ktoré pretekajú Grande São Paulo, sú Tietê a Pinheiros. Zelené krúžky označujú lokality s recentnými záznamami zdokumentovanými fotografiami a nahrávaním zvukov. Satelitné snímky pochádzajú z družice Landsat/Copernicus 2015.

grey literature (i.e., theses, dissertations, and technical reports). Digital databases, such as Web of Science (<https://apps.webofknowledge.com>), Scopus (<https://www.scopus.com/home.uri>) and Google Scholar (<https://scholar.google.com/>), were searched using combinations of the following keywords in Portuguese and English and using the Boolean operators “AND” and “OR”: *Urubitinga urubitinga*, *Buteogallus urubitinga*, gavião-preto, great black hawk. Ornithological collections were checked through the online platform Global Biodiversity Information Facility (GBIF; <https://www.gbif.org/>), including the Museu de Zoologia da USP (MZUSP), the largest ornithological collection in the state of São

Paulo and Brazil. Two data spreadsheets from the Centro de Estudos Ornitológicos (CEO; a non-governmental organization of the city of São Paulo) were consulted, one on the Neotropical Census of Waterbirds and the other from records made in the state of São Paulo (CEO 2021, 2024). Online scientific platforms such as Ornis (<https://www.ornisnet.org>) and SpeciesLink (<https://www.splink.cria.org.br>), online birdwatching platforms such as WikiAves (WA, <https://www.wikiaves.com.br>) and e-Bird (S/ML, <https://ebird.org>), and the wildlife sounds platform Xeno-Canto (<https://xeno-canto.org/>), were also consulted up to 10 December 2024. Only records with documentation were considered.

Primary data

Records were also obtained during ornithological work by the authors F.S. and A.F.A.M. in different locations within Grande São Paulo (mainly in the city of São Paulo) over the last three decades. The author A.F.A.M. is part of the Wildlife Division, a department of the city of São Paulo that has been monitoring biodiversity (especially birds) in the green areas of the city of São Paulo since 1993. Over the last 32 years, around 171 green areas have been and are being monitored, totalling around 1251 days and 4000 field hours. Data were partially published, for instance, in São Paulo (2023). The author F.S. has been studying birds in the Grande São Paulo since 2000 and, in the last 25 years, has visited dozens of locations, including carrying out some long-term studies and monitoring in the same locations, such as the Guarapiranga reservoir, where he has been conducting a continuous study for 25 years, totalling hundreds of days and thousands of field hours. Data obtained in the field have been made available in technical and scientific publications and on the eBird online platform.

Results

The bibliographic research only uncovered the records originally cited by Pinto (1938) and republished by Willis and Oniki (2003) of three individual great black hawks collected between 1934 and 1935 in Butantan in the western region of the city of São Paulo. However, the individual collected in January 1934 by Pinto (MZUSP 14553) was reidentified in 2009 by researcher Sergio Seipke as a juvenile white-tailed hawk (*Geranoaetus albicaudatus*). The two individuals from 1935 (MZUSP 17021 and 17022), donated by Mr. Cavalleiro, were juveniles and are no longer in the collection of the Museu de Zoologia da USP (L. F. Silveira pers. comm.). The search of digital databases produced one record available in CEO (2024) for the Ribeirão Pires region, but the authors did not confirm this (L. F. F. pers. comm.). The search carried out on online birdwatching platforms obtained nine records documented by photographs taken between 2018 and 2024 and made available on WikiAves, with two duplicate records on eBird. These records were made in two municipalities of Grande São Paulo — Salesópolis (east) and Barueri (west) (Fig. 1; Tab. 1). The data from the online platforms show solitary individuals, with eight records of adult birds and only one with juvenile plumage (WikiAves 2024). Among the records available on the eBird platform, 11 were not considered in the present study because they were not documented.

The field records of great black hawks made by the

authors occurred in only two locations in the Grande São Paulo. In January and August 2023 at the Anhanguera Wildlife Refuge, a municipal reserve of approximately 800 ha located in the northern region of the municipality of São Paulo (data partially published in São Paulo 2023), and in September 2024 at Ilha dos Eucaliptos, a state reserve of 32 ha island located in the central part of the Guarapiranga Reservoir, an artificial reservoir inaugurated in 1908, in the southern region of the municipality of São Paulo (Mendes 2000) (Fig. 1; Tab. 1).

In the Anhanguera Wildlife Refuge, the authors A.F.A.M., L.B.Z., L.A.M., S.M.M., G.R.R. and R.M. recorded an adult individual in January 2023, vocalizing and flying over the region, coming from a flooded area of the Juqueri River, relatively close (S126451231, ML627729146). New auditory records, possibly of the same individual, were made in January and August 2023 (eBird: S127097852, S153152796) (Tab. 1). The recording site is bordered by native forest and eucalyptus (*Eucalyptus* spp.) groves, with dead eucalyptus trees. No nest was observed, nor was any reproductive behaviour of the observed individual.

On Ilha dos Eucaliptos, the authors F.S. and G.F.D. recorded an adult individual in September 2024, perched on a nest in construction approximately 20 m high in a dead/dry eucalyptus tree in an area of eucalyptus forest on the island (Fig. 2). The nest was already well built with thick branches. Yet, the bird was still picking up some thinner branches from the nest itself with its beak and arranging them on the main structure (Fig. 3). The individual was observed for approximately 30 minutes when it performed this behaviour and remained alert, as the nest was in a nesting area for waterbirds, such as the neotropical cormorant (*Nannopterum brasilianum*), cocoi heron (*Ardea cocoi*) and great egret (*Ardea alba*). Only the cocoi heron had active nests (under construction and with birds incubating) at the time. The observed great black hawk nest was approximately 6–12 m from the nearest cocoi heron nests. The great black hawk was not observed at the site nor in the region on a second visit three days later, and its nest was also no longer in the respective tree.

Discussion

Grande São Paulo is among the most ornithologically studied locations in Brazil, with approximately 200 years of data already produced on its birds (Pelzeln 1871, Ihering 1898, Pinto 1938, 1944, 1945, Willis and Oniki 2003, Schunck 2008, São Paulo 2023) and the largest number of bird watchers and photographers active in

Fig. 2. Location of the nest of the great black hawk (*Buteogallus urubitinga*) on Ilha dos Eucaliptos, Guarapiranga Reservoir, São Paulo. Nest location on the west bank of the island (red circle), high up in an Eucalyptus grove (A). Detail of the bird on the nest (red circle) and an indication of a cocoi heron (*Ardea cocoi*) nest on the left side, nearby (white asterisk) (B).

Obr. 2. Poloha hniezda myšiaka vodného (*Buteogallus urubitinga*) na ostrove Ilha dos Eucaliptos, nádrž Guarapiranga, São Paulo. Umiestnenie hniezda na západnom brehu ostrova (červený kruh), vysoko v eukalyptovom háji (A). Detail vtáka na hniezde (červený kruh) a označenie hniezda volavky kokoi (*Ardea cocoi*) na ľavej strane, v blízkosti (biela hviezdička) (B).



Brazil (eBird 2024, WikiAves 2024). Thus, the great black hawk is not a species that could have gone unnoticed by naturalists, collectors, ornithologists, bird watchers and photographers who have in some way visited or resided in the region.

The existence of only 13 records made in the last six years (between 2018 and 2024) at four locations offers four following explanations: (1) the species is not a resident because the Alto Tietê Hydrographic Basin has small rivers, compared to those in the interior or on the coast of the state where it is common, in addition to environmental, climatic and ecological issues that may be involved; (2) the species may have been colonizing

artificial wetlands (lakes and dams) of Grande São Paulo in recent years, as has been happening with the silver teal (*Spatula versicolor*), the green ibis (*Mesembrinibis cayennensis*), the bare-faced ibis (*Phimosus infuscatus*) and the great grebe (*Podiceps major*) (Schunck et al. 2025), among others; (3) the species is a regional vagrant in Grande São Paulo, as already determined for several other species, such as the white-winged swallow (*Tachycineta albiventer*) (Dores et al. 2021), since some of the detected individuals were young and adults have not been observed in the same location for an extended period of time and/or (4) the species may be common around the Grande São Paulo and dispersed individuals

Fig. 3. Adult great black hawk (*Buteogallus urubitinga*) on the nest at Ilha dos Eucaliptos, Guarapiranga Reservoir, São Paulo (A). Detail of the bird and the nest (with a branch in its beak) (B).

Obr. 3. Dospelý jedinec myšiaka vodného (*Buteogallus urubitinga*) na hniezde v Ilha dos Eucaliptos, nádrž Guarapiranga, São Paulo (A). Detail vtáka a hniezda (s konárom v zobáku) (B).



Tab.1. Records of the great black hawk (*Buteogallus urubitinga*) obtained for the Grande São Paulo. The locality marked with an asterisk may not be correct and is attributed to the location of records with verified origin. Documentation column: MZUSP - Museu de Zoologia da USP and WA - WikiAves. Source Column: S - eBird Bird List.

Tab.1. Záznamy o myšiakovy vodnom (*Buteogallus urubitinga*) získané pre Grande São Paulo. Lokalita označená hviezdíčkou nemusí byť správna a je priradená k lokalite záznamov s overeným pôvodom. Stĺpec s dokumentáciou: MZUSP - Museu de Zoologia da USP a WA - WikiAves. Zdrojový stĺpec: S - zoznam vtákov eBird.

N°	Locality	Geographic Coordinates	Altitude (m.a.s.l.)	Municipality	Date	Documentation	Author	Source
1	Museu da Energia - Usina Parque	23°33'50.38"S 45°50'16.05"W	784	Salesópolis	7.9.2018	WA3108946, 3172221	Alberto Tamashiro, Vadi Tanaka	WikiAves
	1.5.2021				WA4291449	Roberto Shimizu	WikiAves	
	26.7.2024				WA6232300	Mario Campagnoli	WikiAves	
	4.8.2024				WA6254118	João Victor S. de Sá	WikiAves	
	3.8.2024				WA6312947	Victor Bastos	WikiAves	
2	Parque Ecológico do Tietê, Núcleo Ilha do Tamboré (Parque Ecológico do Tamboré)	23°28'56.91"S 46°52'18.07"W	721	Barueri	29.6.2022	WA4902163	Pedro Cristales, Edilson Pichiliani	WikiAves
	23.12.2022				WA5215206	Edilson Pichiliani	WikiAves	
	6.4.2024				WA6013307	Henrique Junior	WikiAves	
	Not informed				WA6117462	Leandro Moreira	WikiAves	
	18.1.2023				ML627729146 WA6612412	Anelisa Magalhães, Leticia B. Zimback, Lucas A. de Matos, Sylvia M. Matsuda	eBird (S126451231) Present study	
3	Refúgio de Vida Silvestre Anhanguera, Trilha Lago das Garças/Paliteiro	23°24'46.70"S 46°47'31.29"W	795	São Paulo	27.1.2023		Anelisa Magalhães, Leticia B. Zimback, Gisele R. Ruy, Rafaella da Mata	eBird (S129838879) Present study
	22.8.2023					Anelisa Magalhães, Leticia B. Zimback, Rafaella da Mata, Ravi A. Carmo, Estela Torres	eBird (S153152796) Present study	
4	Represa do Guarapiranga, Ilha dos Eucaliptos	23°44'2.94"S 46°44'1.55"W	739	São Paulo	26.9.2024	Figures 2 and 3	Fabio Schunck, Gustavo F. Diniz	eBird (S197888964) Present study

try to colonize the favorable environments of this region, as presented by Leveau et al. (2022) in Argentina.

The records made at the Anhanguera Wildlife Refuge are the first for the municipality of São Paulo and show a different type of occurrence in smaller artificial lakes, which has not been previously detected in this area. Suppose it was the same individual that was detected on all three occasions, mainly between January and August, then the pattern is similar to that observed at other locations, with birds that seem to spend a few months in the same area, probably due to the availability of food or for recovery in the case of regional vagrant individuals. The record made on Ilha dos Eucaliptos is very striking, both because it was of a bird with a nest, being the first documented record for the state of São Paulo, where its reproduction was speculated (Willis and Oniki 2003) and because it was located in a waterfowl nesting area,

an important source of food for the species (e.g., eggs and heron chicks) (Olmos 1990, Sick 1997). The date of the record (September) and the behaviour of arranging the branches of the nest coincide with the nest-building period reported by Carvalho Filho et al. (2006) in Minas Gerais.

Most of the current records of the great black hawk for Grande São Paulo were made in flooded areas, such as lakes and reservoirs associated with the Pinheiros and Tietê rivers. However, there are several locations (mainly reservoirs) with suitable habitats that do not yet have records of the species, which need to be visited and monitored in the future.

We also highlight the importance of carrying out monthly monitoring programs for birds in Grande São Paulo, since the record made at the Anhanguera Wildlife Refuge was part of the "Inventory and Monitoring of

Wildlife in the Municipality of São Paulo” program carried out by the Divisão da Fauna Silvestre (DFS) of the City of São Paulo continuously since 1993 (São Paulo 2023). The record made on Ilha dos Eucaliptos was part of a monthly monitoring of aquatic and migratory birds carried out at the Guarapiranga reservoir by the author F.S. and collaborators.

Although incomplete, the great black hawk breeding record in the Grande São Paulo is noteworthy for being the first documented nest for the state of São Paulo, where the species is widely found and has been frequently recorded. Breeding in the state by the species was predicted by Willis and Oniki (2003). Still, among the 957 images of the species available on the two main online platforms (749 on WikiAves and 208 on eBird), only records of mating birds (e.g., ML488978891) and young birds of different ages (e.g., ML176955661, 6230001901) were found. The record of the nest on Ilha dos Eucaliptos and the online data support the possibility of breeding in São Paulo state. It would be essential to map the locations with data on reproductive behaviour and the presence of young birds so that nests can be found and monitored in the future. This type of information is scarce for this species, especially in Southeast Brazil, and essential for conservation actions.

Records made by birdwatchers and photographers are essential for carrying out this type of monitoring and for understanding the occurrence of the great black hawk in Grande São Paulo over time. However, 11 of all the records available on the eBird platform were not considered in the present study, as they were undocumented (eBird 2024). Since this species, whether in adult or juvenile plumage, can easily be confused with other species of hawks that occur in the same environments, such as the snail kite (*Rostrhamus sociabilis*) and Harris’s hawk (*Parabuteo unicinctus*), we cannot be certain about these identifications. However, if accurate, they may indicate that the species is more common than previously thought. Therefore, we recommend that all records of the great black hawk (and other species, including hawks) made in Grande São Paulo be documented and posted on online birdwatching platforms. We also advise that exact locations be provided, as some records made in Salesópolis may have the wrong location due to the observer having visited one area but made the record in another.

The occurrence of the great black hawk in the wetlands and flooded areas of Grande São Paulo, whether natural or artificial, draws attention to the existence of this type of environment in the vicinity of the largest

urban area in South America. It also calls attention to the need to expand the protection of these habitats, mainly by creating conservation units in the floodplains associated with the Tietê River. These environments are essential for conserving the entire community of birds related to the wetlands of Grande São Paulo, including dozens of endangered species.

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Case report and prey analysis of ground-nesting eagle owls (*Bubo bubo*) in Slovakia

Správa o rozboře potravy a zemnom hniezdení výra skalného (*Bubo bubo*) na Slovensku

Samuel PAČENOVSKÝ, Karol ŠOTNÁR & Ján OBUCH

Abstract: In current ornithological literature, there is a general consensus that the eagle owl (*Bubo bubo*) is a breeder of rocky habitats in Slovakia, especially on cliffs and quarry walls, but little research to date has concentrated on cases of ground-nesting in the lowland areas of the country. This study provides an overview of the documented cases of eagle owls breeding in lowland forests, a relatively unusual method of breeding for this species. The authors also report a recent case of an eagle owl breeding on the ground in a floodplain forest at the small settlement of Sedín near the forest edge in the western part of the Danube Lowlands. The nest was located in a shallow basin at the base of a large white poplar (*Populus alba*) tree, just 3 m from an oxbow lake. The site was visited three times between 12 April and 12 May 2024, and three young birds were observed in the nest, all of which likely fledged successfully. Prey remains from the nest were analysed and the results are presented here together with those of five other eagle owl nests from the lowlands of Slovakia and the Czech Republic. In the nest near Sedín, the common hamster (*Cricetus cricetus*) was the predominant prey species, in contrast to a location near Vojčice in the East Slovak Lowlands in which the brown rat (*Rattus norvegicus*) predominated or nest sites in Southern Moravia and the Třeboňsko region of the Czech Republic where larger birds were the main prey.

Abstrakt: V ornitologickej literatúre je v podmienkach Slovenska zaužívaný názor, že výr skalný (*Bubo bubo*) je hniezdíčom skalných biotopov - predovšetkým skalných stien a kameňolomov, ale takmer chýbajú údaje o hniezdení na zemi v nížinách. Autori popisujú doteraz evidované prípady z pohľadu Slovenska nezvyčajného hniezdenia výra skalného z literatúry, ktoré sa našli na stromoch a v lužných lesoch a podrobne popisujú aktuálny nález zemného hniezdenia výra v lužnom lese v západnej časti Podunajskej roviny. Hniezdo bolo umiestnené v starom mäkkom luhu, pri osade Sedín neďaleko okraja lesného porastu; na zemi v nevýraznej kotlinke pri päte veľkého bieleho topoľa (*Populus alba*), len 3 m od okraja vody – mŕtveho ramena. Hniezdo bolo medzi 12. aprílom a 12. májom 2024 navštívené trikrát. V hniezde boli 3 mláďatá, ktoré s veľkou pravdepodobnosťou úspešne vyleteli. Potrava výrov z tohto hniezda bola podrobená analýze, spoločne s 5 inými hniezdeniami výra v rovinatých častiach Slovenska a Českej republiky. Na lokalite Sedín na Podunajskej rovine bol početnejšie zastúpený chrček poľný (*Cricetus cricetus*), na lokalite Vojčice na Východoslovenskej rovine potkan hnedý (*Rattus norvegicus*), na južnej Morave a na Třeboňsku väčšie druhy vtákov.

Key words: eagle owl, nesting site, breeding habits, feeding ecology, Strigidae

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Introduction

In Slovakia, the eagle owl (*Bubo bubo*) typically breeds in rocky habitats such as active or disused quarries, or on cliffs and other smaller rocky formations. Other types of breeding site, such as ground nests in forested areas or steep rocky slopes which are overgrown by bushes, are relatively rare, but when there is a lack of their favoured rocky sites, eagle owls can breed also in

forests, either below the roots of fallen trees or among the roots of standing trees, as has been observed in, for example, the Orava Highlands, the Orava Magura range, the Skorušinské Mountains, the Vihorlat Mountains, the southern part of the Laborec Highlands and the Ondavská Highlands. The species does not breed deep in the forests, preferring instead wooded edges near open country (Danko & Karaska 2002).

The habitat of the eagle owl has been characterised as follows: “This species inhabits mainly rocky country with cliffs and ravines, caves, patches of woodland, scattered trees or groves, generally in undisturbed wilderness areas. It also uses open forest, taiga and other types of woodland, wooded steppe, river valleys with gorges, overgrown quarries and farmland with suitable rocky areas or cliffs. Occasionally it uses old tree nests of other species and rarely tree holes” (BirdLife International 2024, Hagemeyer & Blair 1997). Nonetheless, eagle owls have been almost exclusively associated with cliffs and boulders for many decades, undoubtedly because the overwhelming majority of studies published in English, Spanish, French or German are based on research carried out in rocky areas. The linguistic barrier which limits access to works published in, for example, Finnish and/or Russian, has prevented many people outside of the boreal range from associating the eagle owl with flat terrain, forests and clear-cuttings, although we should bear in mind that the distribution range of the species largely overlaps with boreal forest regions (Penteriniani & del Mar Delgado 2019). A similar share of habitats was also determined on the territory of the former Czechoslovakia: from 158 identified nests, 83 (52.6%) were located among rocks, 50 (31.6%) on a forested slope below a boulder or beside it; 12 (7.6%) among the underground roots of a fallen tree, 1 (0.6%) in the cavity of a tree stump, 4 (2.5%) among debris on a quarry slope, 2 (1.3%) in the walls of a castle ruin, 6 (3.9%) in raptor nests in varying heights in trees, and 1 (0.6%) in an old hunting lodge (Hudec et al. 1983). The frequent use of raptor nests in trees by eagle owls is well known in the Czech Republic (Bělka & Diviš 1989, Bělka & Crúz 1992).

Cases of eagle owls nesting in forests by eagle owls, either in ground nests in stumps or around roots and fallen trees or in former nests of raptors and storks in trees are also known in Belarus (Gričik 2004). An analysis of older breeding data from Sweden mentioned by Olsson (1979) noted that 80% of nests were found in rocky areas; the remaining 20% were located on the ground (Mikkola & Willis 1983). In the Czech Republic, an eagle owl was even found nesting in a red fox (*Vulpes vulpes*) den (Šťastný et al. 2006).

In Slovakia, the first case of an eagle owl breeding in a former raptor nest was found at Plavecké Podhradie in 1979 (Danko et al. 2002). Another example was found on 13.5.2004, when a female was observed with a chick in a former lesser-spotted eagle (*Aquila pomarina*) nest (Šotnár 2007). A possible breeding attempt in a lowland

floodplain forest was described by Noga (2005). A further case of nest-breeding was found in a narrow buffer zone of trees near the Senné fishponds at Blatná Polianka (Pačenovský et al. 2012), with eagle owls using a former white-tailed eagle (*Haliaeetus albicilla*) nest in 2011 and 2012; the site was used repeatedly until 2016 (Chrašč unpubl. in Danko et al. 2017) when the nest complete disintegrated. Data from the East Slovak Lowlands shows that eagle owls started to move to the lowlands from nearby hilly areas in around 2010 (Danko et al. 2017). A further case of breeding in an old raptor nest in a lowland floodplain forest by the Danube was described by Šotnár (2021).

Some examples of eagle owls breeding in non-rocky habitats, including ground-nesting and breeding in lowland floodplain forests and other lowland environments, from different parts of Europe but especially in Central Europe reported in literature from between 1980 and 2024 are listed and quantified in Table 1.

As early as the 1980s, the breeding of eagle owls close to human settlements was observed with growing frequency in Northern Europe, with the nocturnal activity of the owls enabling them to avoid human activities (Mikkola & Willis 1983). In recent decades, the species has also nested in small forest patches beside fields or near human settlements in Southern Bohemia (Kloubec et al. 2015). Of the 11 eagle owl breeding sites which were known to be active in Malá Fatra National Park throughout the 1980s, only 4 remained occupied in the period 2012–2017; this population decrease is likely explained by the loss of hunting grounds due to changes in land management followed by the afforestation of the surrounding open areas (Flajs 2017).

Between 2013 and 2017, Šnír et al. (2018) recorded 87 breeding attempts by 30 eagle owl pairs in Ponitrie region in the northern part of Nitrianska Pahorkatina and the margins of the Tribeč Mountains, the Strážov Mountains and Považský Inovec, an area of 1440 km²; 15 pairs in quarries, 5 in rocks, 3 in forests (1 in a tree and 1 on the ground) and 1 pair in a castle ruin. It has also been hypothesized that ground-breeding of eagle owls is probably more widespread but overlooked in areas without rocky habitats (Danko, Karaska in: Danko et al. 2002).

An extensive study of the diet of the eagle owl across much of its Palearctic distribution area was recently published by Obuch (2024). The study noted a long-term change in the overall survival strategy of the species in Slovakia (Obuch 2021). The majority of the eagle owl population now breeds on the edges of mountain valleys; in the past, they hunted small mammals and amphibians

Tab. 1. Known cases of ground-nesting of eagle owls and nesting in forested areas in some Central-European countries and Europe as a whole from 1980–2024.

Tab. 1. Známe prípady zemného hniezdenia a iných spôsobov hniezdenie v zalesnených oblastiach u výra skalného v strednej Európe aj v širšom okolí v rámci Európy v rokoch 1980-2024.

nest specification	country/region/site	No of cases	citation
ground-nesting	Sweden	20% of all cases	Olsson 1979
ground-nesting	former Czechoslovakia	12	Hudec et al. 1983
ground-nesting on a clay slope	Slovakia	1	Karaska 1995
ground-nesting on abandoned railway bridge	Slovakia	1	Karaska 1995
ground-nesting	Czech Republic	1	Červený & Obuch 1999
ground-nesting	Belarus	No of cases not specified	Gričik 2004
ground-nesting	Czech Republic	1	Šťastný et al. 2006
ground-nesting	Slovakia	1	Šnírer et al. 2018
on a building - Bojnice castle tower	Slovakia	1	Danko et al. 2000
in former raptor nest	Plavecké Podhradie, Slovakia	1	Danko et al. 2002
in lowland forests	West Slovakia	1	Noga 2005
in heron and stork nests	Czech Republic	No of cases not specified	Šťastný et al. 2006
in a fox den	Czech Republic	1	Šťastný et al. 2006
in lesser-spotted eagle nest	Opatovce nad Nitrou, Prievidza district, Slovakia	1	Šotnár 2007
in a nestbox for sakers on an electricity “pylon; 1 pair bred in 2008-12 “	Budkovce, East Slovakia	5	Mihók & Lipták 2010
in ruins of a building	near Trebišov, East Slovakia	1	Hrtan 2010
in a nestbox for saker falcons in a tree, in a floodplain forest	South Moravia	2	Horal & Škorpíková 2011
in former white-tailed eagle tree-nest, in a floodplain forest	South Moravia	1	Horal & Škorpíková 2011
in former goshawk nest, in a floodplain forest	South Moravia	1	Horal & Škorpíková 2011
in former black stork nest, in a floodplain forest	Austria	1	Horal & Škorpíková 2011
in former raptor nest, in a floodplain forest	Austria	1	Horal & Škorpíková 2011
in former white-tailed eagle nest, 1 pair bred in 2011-16	Blatná Polianka, East Slovakia	6	Pačenovský et al. 2012, Danko et al. 2017
in old black stork nest, 3 pairs	between Pácin and Strážne villages, Hungary	3	Danko et al. 2017
in former common buzzard nest	between Pácin and Strážne villages, Hungary	1	Danko et al. 2017
in probable former white-tailed eagle nest	Danube Lowlands, Slovakia	1	Šotnár 2021

on pastureland located deep in the mountains, but they have recently adapted to hunting larger prey in more intensively farmed valleys (Obuch 2021).

Another case of ground-nesting by eagle owls was found in 2024 in a floodplain forest in the western part of the Danube Lowlands. The breeding record is described below.

Methods

The nest was observed during 3 daytime visits from a distance of 20 m using 12x50 binoculars. The timing of the checks was minimised in order to avoid disturbance. The area is known as the former breeding site of a pair of white-tailed eagles, and the eagle nest is located only 500 m from the ground nest of the eagle owl; white-tailed

eagles are known to have used the nest until 2020. The surrounding area of the extensive floodplain forest along the Malý Dunaj River is open agricultural land; part of the area is also used as a golf course from April until the autumn months.

The young birds were ringed, and prey remains and pellets were collected from the nest. The pellets were broken down in 5% NaOH and washed in water. After the bones had dried, the following material was identified: mammal jawbones, four types of bird bones (beaks, *humerus*, *metacarpus* and *tarsometatarsus*), frog hip bones (*os ilium*), insect heads and jaws. The abundance of specific species was determined as the minimum possible number based on the most commonly identified body parts (Minimum Number of Individuals, MNI). The results were compared using the methodology of marked difference from the mean (MDFM, Obuch 2001) and presented in the form of a contingency table with differences 1+ and 1-

Results

The nest was found on 12 April 2024 near the edge of a floodplain forest close to the settlement of Sedín in the cadastral area Nové Osady, ca 6 km south of the village of Veľké Úľany in the western part of the Danube Lowlands. Inside the nest were 3 small, white nestlings of around 10–14 days old (Fig. 1). The ground nest of the eagle owl was located at the foot of a white poplar (*Populus alba*) tree on the bank of an oxbow lake, only 3 m from water (Fig. 2). The second visit to the nest was carried out on 14 April and the nest was observed from the opposite bank of the oxbow

lake. An adult female eagle owl was guarding its young chicks; she was lying on the nest and did not leave.

The third visit was performed on 12 May. The nest itself was only a small area dug into forest soil, directly below a tree, hidden from its surroundings by low bushes. By this time the young birds were about 6–7 weeks old and were found at a distance of 3 to 8 m from their nest. The female was observing them from the surrounding trees.

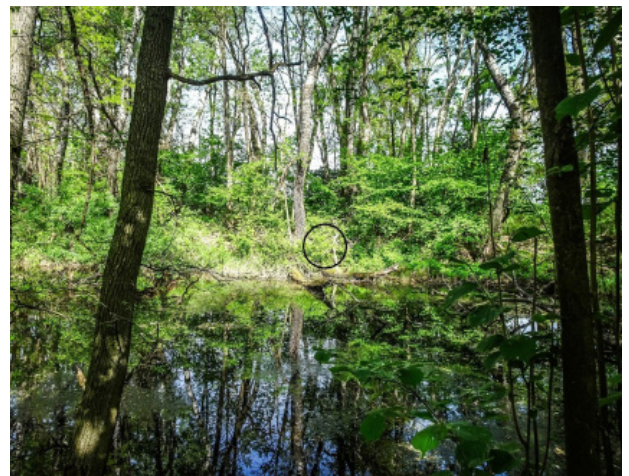


Fig. 2. Nest site of eagle owl (*Bubo bubo*) at the base of a white poplar tree (*Populus alba*), indicated with a circle (Photo: K. Šotnár).

Obr. 2. Hniezdo výra skalného (*Bubo bubo*) pri päte topoľa bieleho (*Populus alba*), miesto vyznačené kruhom (Foto: K. Šotnár).



Fig. 1. Eagle owl (*Bubo bubo*) nestlings, aged 10–14 days, with several prey items found in the nest during the first check (Photo: S. Pačenovský).

Obr. 1. Mláďatá výra skalného (*Bubo bubo*) vo veku 10 - 14 dní, so zvyškami potravy nájdenými počas prvej kontroly pri hniezde (Foto: S. Pačenovský).

Six samples of prey remains from eagle owl nest sites located in the lowlands of Slovakia and the Czech Republic were also analyzed (Table 2). The most abundant prey item at the Sedín site was the common hamster (*Cricetus cricetus*); at Vojčice in the East Slovak Lowlands the brown rat was predominant (*Rattus norvegicus*), while larger species of birds prevailed in Southern Moravia and the Třeboňsko region.

Discussion

Our observations confirmed earlier suggestions regarding the inconspicuous nature of eagle owls; their breeding activities can often escape attention, especially in areas without rocky formations or quarries. The distribution shift of eagle owls towards lowland areas of Slovakia with a lack of rocky areas is probably connected with a wider availability of larger prey, both in terms of mammals and birds. Traditional breeding sites on rocks are often

Tab. 2. Vzorky potravy výra skalného (*Bubo bubo*) z rovinatých častí Slovenska a Českej republiky
Tab. 2. Food samples of eagle owl (*Bubo bubo*) from the lowlands of Slovakia and the Czech Republic.

Species \ Sample No	1	2	3	4	5	6	Total	%			
<i>Erinaceus roumanicus</i>		1		1	1		3	2.34			
<i>Lepus europaeus</i>	3		1	4			8	6.25			
<i>Mus cf. musculus</i>	1						1	0.78			
<i>Apodemus flavicollis</i>	1						1	0.78			
<i>Apodemus microps</i>	1						1	0.78			
<i>Rattus norvegicus</i>	7	1	1+	8	1		17	13.28			
<i>Cricetus cricetus</i>	1+	12	1	1	2	1	17	13.28			
<i>Arvicola amphibius</i>			1			1	3	3.91			
<i>Microtus arvalis</i>			2	3	1+	10	1	16	12.50		
<i>Microtus agrestis</i>							1	1	0.78		
Mammalia	1+	25	3	13	11	13	1-	5	70	54.69	
<i>Anas platyrhynchos</i>		1		4	1	1	7	5.47			
<i>Falco tinnunculus</i>					1		1	0.78			
<i>Perdix perdix</i>				4	1		5	3.91			
<i>Phasianus colchicus</i>				2			2	1.56			
<i>Gallinula chloropus</i>			1	1			2	1.56			
<i>Fulica atra</i>						1	1	0.78			
<i>Chroicocephalus ridibundus</i>						1+	10	10	7.81		
<i>Columba livia domestica</i>					1		1	0.78			
<i>Streptopelia decaocto</i>					1		1	0.78			
<i>Streptopelia turtur</i>				1			1	0.78			
<i>Bubo bubo</i>				1			1	0.78			
<i>Asio otus</i>				1	2		3	2.34			
<i>Strix aluco</i>				1	3		4	3.13			
<i>Anthus trivialis</i>	1						1	0.78			
<i>Phylloscopus trochilus</i>	1						1	0.78			
<i>Turdus merula</i>				2		1	3	2.34			
<i>Turdus philomelos</i>					1	1	2	1.56			
<i>Passer domesticus</i>	1						1	0.78			
<i>Oriolus oriolus</i>				1			1	0.78			
<i>Garrulus glandarius</i>				1			1	0.78			
<i>Corvus cornix + frugilegus</i>				1			1	0.78			
Aves	1-	3	1	1-	1	1+	20	11	14	50	39.06
<i>Pelophylax cf. esculentus</i>						1	1	0.78			
Amphibia	0	0	0	0	1	0	1	0.78			
Coleoptera sp.					1	5	6	4.69			
<i>Gryllotalpa gryllotalpa</i>			1				1	0.78			
Evertebrata	0	0	1	0	1	5	7	5.47			
Total	28	4	15	31	26	24	128	100			

Sample No: 1 - Sedín, 12.5.2024, ground nest, leg. K. Šotnár, 2 - Dolný Chotár, 3.6.2021, below nest tree, leg. K. Šotnár, 3 - Vojčice, 21.5.2010, on building, leg. E. Hrtan, SRJ 2010, 4 - Břeclav, Trnavá, 1.10.2019, leg. H. Matušík, 5 - Lanžhot, Zaječí jezero, 1.10.2019, leg. H. Matušík, 6 - Novořecká hráz, 26.7.1993, Červený & Obuch 1999.

Lokality: 1 - Sedín, 12.5.2024, hniezdo na zemi, leg. Šotnár, 2 - Dolný Chotár, 3.6.2021, pod.hniezdnym stromom, leg. K. Šotnár, 3 - Vojčice, 21.5.2010, v budove, leg. E.Hrtan, SRJ 2010, 4 - Břeclav, Trnavá, 1.10.2019, leg. H. Matušík, 5 - Lanžhot, Zaječí jezero, 1.10.2019, leg. H. Matušík, 6 - Novořecká hráz, 26.7.1993, Červený & Obuch 1999.

abandoned by eagle owls due to the growing disturbance posed by tourists and rock climbers (Obuch 2021), while traditional feeding habitats in mountains are also increasingly abandoned due to afforestation (Flajs 2017).

A growing number of eagle owl pairs are known to nest in forested lowland areas (Pačenovský et al. 2012, Danko et al. 2017, Šotnár 2021). Only small amounts of prey remains have been found at these lowland nest sites, a finding which suggests the short-term utilisation of these nests. At less suitable breeding sites a higher mortality rate among chicks was observed, and we therefore assume that eagle owls can find better food supplies with more optimal prey size in lowland regions, but that they also face a higher risk of the predation of young (Obuch 2024).

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Movement patterns, roosting sites and diet composition during the breeding season of three different forest-dwelling owl species in an area of sympatry: a case study of male home ranges

Pohybové vzorce, miesta odpočinku a zloženie potravy troch sympatricky žijúcich druhov lesných sov počas hniezdneho obdobia: prípadová štúdia domovských okrskov samcov

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Abstract: In areas of sympatry, animals face risks associated with predation pressure and competition for space and/or food from individuals within the same or different ecological guilds. In birds of prey, intraguild competitors and adversaries may adapt to coexistence through various mechanisms, such as spatial avoidance, dietary differentiation, or using distinct habitat types in the shared environment. However, studies examining multiple sympatric owl species and simultaneously investigating their home ranges, diet, and roosting sites remain exceptional. Therefore, we studied four sympatric owl species to obtain findings on spatial arrangements of their diurnal roosting home ranges, and prey and habitat selection during the breeding season. Individual males from three of the four studied species [Eurasian pygmy owl (*Glaucidium passerinum*), boreal owl (*Aegolius funereus*), and tawny owl (*Strix aluco*)] were radio-tracked in an area co-inhabited by an apex intraguild predator, the Eurasian eagle-owl (*Bubo bubo*). The diurnal roosting home range, calculated using a 95% kernel density estimation method, was 111, 117, and 7 ha for the pygmy, boreal, and tawny owl male, respectively. The diurnal roosting home ranges overlapped by 55% in the case of the boreal and pygmy owl males; in contrast, their ranges overlapped only by 2% and 4%, respectively, with that of the tawny owl male. The tawny owl male roosted at a respectful distance from the eagle-owl's nest site in all recorded cases, while it was included within the diurnal roosting home ranges of both smaller owl species, indicating the subordinate owl species may use the presence of an apex predator to protect themselves from medium-intraguild enemies. The study results suggest that intraguild competitors/enemies may mitigate direct conflict through spatial avoidance and dietary differentiation, and such partial niche separation may help reduce food competition within the guild, promoting coexistence among species.

Abstrakt: V oblastiach sympatrickeho výskytu čelia živočíchy rizikám spojeným s tlakom predátorov a konkurenciou o priestor a/alebo potravu zo strany jedincov v rámci rovnakých alebo odlišných ekologických gíld. U dravých vtákov sa vnútrodruhová konkurenti a protivníci môžu adaptovať na koexistenciu prostredníctvom rôznych mechanizmov, ako je priestorové vyhýbanie sa, potravinová diferenciácia alebo využívanie odlišných typov biotopov v zdieľanom prostredí. Avšak štúdie skúmajúce viacero sympatrických druhov sov a súčasne analyzujúce ich domovské okrsky, potravu a miesta odpočinku zostávajú výnimočné. Preto sme študovali štyri sympatrické druhy sov s cieľom získať poznatky o priestorovom usporiadaní ich denných hniezdných domovských okrskov a výbere koristi a biotopov počas hniezdneho obdobia. Jednotliví samce troch zo štyroch študovaných druhov [kuvičok vrabčí (*Glaucidium passerinum*), pôtik kapcavý (*Aegolius funereus*) a sova lesná (*Strix aluco*)] boli rádiovo sledované v oblasti spoluobývanej vrcholovým vnútrogildovým predátorom, výrom skalným (*Bubo bubo*). Denný odpočinkový domovský okrsek, vypočítaný pomocou metódy 95% odhadu jadrovej hustoty, bol 111, 117 a 7 ha pre samca kuvička, pôtika a sovy lesnej. Denné hniezdne domovské okrsky sa prekrývali na 55 % v prípade samcov pôtika a kuvička; naopak, ich okrsky sa prekrývali len na 2 % a 4 % s okrskom samca sovy lesnej. Vo všetkých zaznamenaných prípadoch samec sovy lesnej odpočíval v značnej vzdialenosti od hniezdiska výra skalného, ktoré však bolo zharnuté v dennom odpočinkovom okrsku oboch menších druhov sov, čo naznačuje, že nižšie postavené druhy sov môžu využívať prítomnosť vrcholového predátora na ochranu pred stredne veľkými vnútrogildovými nepriateľmi. Výsledky štúdie naznačujú, že vnútrogildoví konkurenti/nepriatelia môžu zmierňovať priamy konflikt prostredníctvom priestorového vyhýbania sa a potravinovej diferenciácie, a takéto čiastočné rozdelenie niky môže pomôcť znížiť potravnú konkurenciu v rámci zoskupenia, čím podporuje koexistenciu medzi druhmi.

Key words: diurnal roosting, Eurasian pygmy owl, intraguild relationships, radio-telemetry, tawny owl, boreal owl

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Introduction

A diverse range of intra- and inter-species interactions, ranging from predation through food competition to obligatory cooperation (e.g., mutualism), have been examined across various organisms. Competition between territorial species is usually most intense among individuals of the same sex, and body size and/or mass commonly serve as the decisive factor in determining the outcomes of mutual competition or the trophic level of species within food chains (Begon et al. 2006). Exploitation competition represents the indirect interaction between competitors (intra- or inter-specifics) as they each deprive the other by utilising the same resources, i.e., they are sharing food, environmental and/or space niches (Nilsson 1984; Alatalo et al. 1987; Sarà et al. 2005). Interference competition refers to competitors directly preventing other individuals from obtaining access to resources (Dhondt 2012; Lang and Benbow 2013); this type of interaction involves various mechanisms, including the predation of adults or immature individuals (Case and Gilpin 1974; Schoener 1983). In extreme cases of interference competition, aggressive clashes can even result in death, and if an individual is consumed by his adversary in the course of this competition, the phenomenon is referred to as intraguild predation (Polis et al. 1989; Lourenço et al. 2014).

These ecological relationships significantly influence animals' areas of occurrence, distribution and home range sizes at both the conspecific and heterospecific levels (e.g., Don 1983; Ribble and Stanley 1998; Kajtoch et al. 2016). When selecting a habitat, animals evaluate various factors, e.g., the presence and abundance of competitors and predators. This behaviour becomes especially pronounced before the critical reproductive phase, such as the breeding season in birds (Fretwell and Lucas 1969; Grand and Dill 1999; Kajtoch et al. 2016; Morosinotto et al. 2017).

Intraguild predation and competition are common among birds of prey, with species size playing a key role in shaping the predation patterns (Mikkola 1983; Sergio and Hiraldo 2008; Solonen 2011; Björklund et al. 2016; Kouba et al. 2023; 2024). Dominant species of birds of prey are known to prey upon and interfere with subordinate ones (Mikkola 1983; Hakkarainen and Korpimäki 1996; Sergio et al. 2003). Additionally, intraguild adversaries typically compete for food resources (Mikkola 1983), and their dietary composition varies in specialisation and diversity. For instance, the boreal owl (*Aegolius funereus*) specialises mainly in *Microtus* and *Myodes* voles (Korpimäki and Hakkarainen 2012), the Eurasian pygmy owl (*Glaucidium passerinum*) frequently supplements its diet with passerine birds (Mikusek et al. 2001; Šotnár et al. 2015), and the tawny owl's (*Strix aluco*) diet is highly diverse and includes even amphibians and reptiles (Obuch 2011). However, despite their differences in body size, all these owl species primarily prey upon small mammals (König and Weick 2008), leading to an overlap in their food niches.

The three above-mentioned owl species also inhabit similar habitat types, primarily mature and/or old coniferous and mixed forests (König and Weick 2008) and habitat sharing results inevitably in a higher likelihood of their food resource competition (Pełowska-Marczak 2019). For example, boreal owls have been found to hunt in patches with high vole densities, leading to their loss and, in the end, decreased hunting success of pygmy owls (Korpimäki and Norrdahl 1989). The latter species also had to limit or avoid the best hunting patches when foraging under the boreal owl predation risk (Suhonen et al. 2007).

Despite the aspects mentioned above, the long-term coexistence of intraguild enemies is common; however, this cohabitation typically impacts the overall fitness of subordinate species (Hakkarainen and Korpimäki 1996;

Solonen 2011; Kajtoch et al. 2016; Morosinotto et al. 2017). As a result, subordinate owl and raptor species are compelled to avoid dominant ones by adopting temporal or spatial segregation strategies (e.g., Jaksić 1982; Sergio et al. 2007; Kajtoch et al. 2016). Alternatively, smaller species may choose to avoid habitats associated with high predation risk, such as those preferred by predator species, a behaviour known as “habitat-mediated avoidance” (Sergio et al. 2007). This pattern can result in a concentration of smaller bird of prey species in refugia free of enemies (Sergio et al. 2003).

This study aimed to investigate simultaneously multiple Strigiformes species to obtain findings on sizes, overlaps and spatial arrangements of their diurnal roosting home ranges, as well as their prey and habitat selection during the breeding season. Individual pygmy, boreal, and tawny owl males were radio-tracked in an area of sympatry where an additional apex intraguild predator,

the Eurasian eagle-owl (*Bubo bubo*), was also present. The current study complements the previously published one, focusing exclusively on hunting home range sizes and overlaps of the same individuals (Stehlíková Sovadinová et al. 2025).

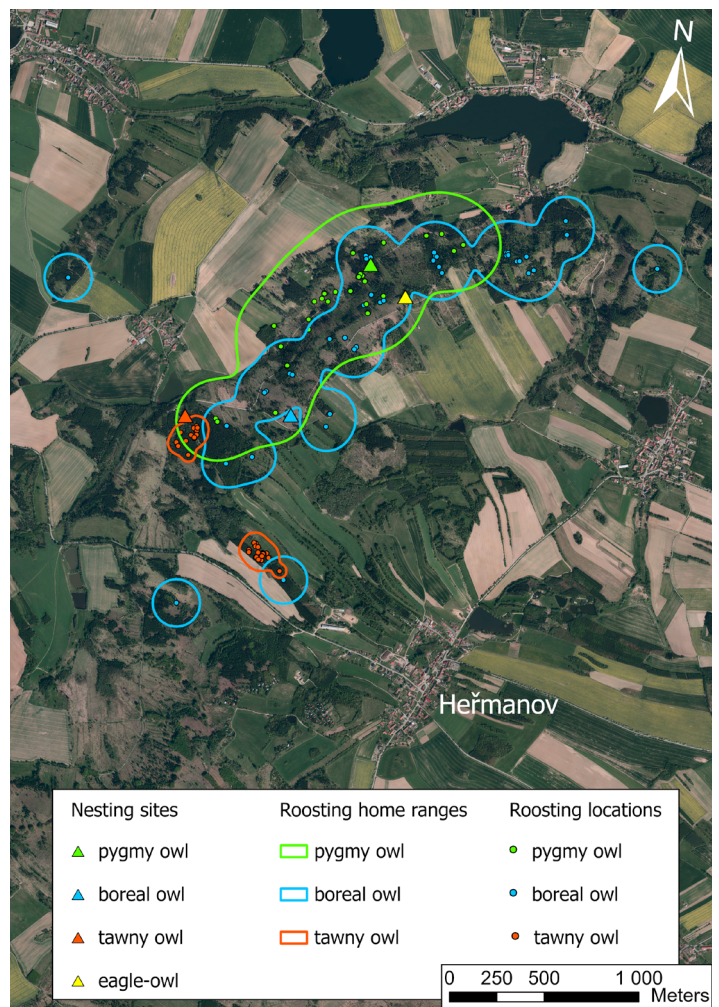
Materials and Methods

Study Area

The study was conducted in Křižanovská vrchovina (the Krizanov Highlands) in the Vysočina region of Czechia (49° N, 16° E; ~500–660 m a. s. l.). The study area covers ~6 square km (depicted on the map with the recorded diurnal roosting home ranges; see Fig. 1). It is comprised of commercial forests (54%), agriculture areas (41%), bodies of water (3%) and human settlements (2%). The oldest local forest stands are over 50 years of age, but the majority (65%) are young to middle-aged (~30 years). Norway spruce (*Picea abies*) was

Fig. 1. Diurnal roosting home ranges of the monitored male owls. The nest sites, locations recorded during resting and diurnal roosting home ranges (calculated using the 95% Kernel Density Estimation method) recorded during breeding for the three radio-tracked male owls. The data for individual species are depicted as follows: Eurasian pygmy owl – green, boreal owl – blue, tawny owl – orange, and Eurasian eagle-owl nest site only – yellow.

Obr. 1. Denné odpočinkové okrsky sledovaných samcov sov. Hniezdiská, pozície zaznamenané počas odpočinku a denné odpočinkové okrsky (vypočítané metódou 95% Kernel Density Estimation) zaznamenané počas hniezdenia troch rádiovo sledovaných samcov sov. Údaje pre jednotlivé druhy sú znázornené nasledovne: kivičok vrabčí - zelená, pôtik kapcavý - modrá, sova lesná - oranžová a výr skalný - žltá.



the predominant species in the forested areas (68%), complemented by stands of mixed deciduous trees (10%) and Scots pine (*Pinus sylvestris*; 7%). Sapling and clear-cut areas formed 15%. Due to the lack of natural nesting cavities within the study area, nest-boxes for boreal and tawny owls were installed around the site.

Field Procedures

From the end of February 2022, we monitored the vocal activity of owls and regularly visited local nest-boxes (installed in 2019) and known natural tree cavities in the study area. Nests of all four owl species (pygmy, boreal, tawny, and eagle-owl) were identified in the locality during March. The pygmy owl pair nested in a natural cavity, the boreal and tawny owl pairs laid clutches in nest-boxes, and the eagle-owl pair nested on a low rocky cliff. Their nests were visited regularly to determine hatching dates (± 2 days) and to count the number of eggs, hatchlings and fledglings (Table 1). However, the clutch of the eagle-owl

pair disappeared soon after laying. This unfortunate incident prevented us from monitoring all four males with radio-tracking because our efforts to capture the eagle-owl male without an active nest were unsuccessful. The three other owl males were attracted to the vicinity of their nests using conspecific whistling or playbacks of prey species cries and were captured using mist nets and an appropriate decoy dummy on 29 March. The captured males were weighed and ringed, and their age was estimated based on the stage of the moulting cycle. Each individual was equipped with an Ag386 VHF radio-transmitter (Lotek Wireless Inc., UK), which was attached as a backpack and released at the capture site. The transmitter weights (Table 1) did not exceed 3% of the tagged individual's body mass (Withey et al. 2001). The three males were subsequently monitored using handheld receivers Yupiteru MVT-9000 (Yupiteru Industries Co. Ltd., Japan) and 3-element Yagi antennas.

The monitoring via radio-tracking was carried out from 30 March until 24 June. The locations of diurnal roosting

Tab. 1. Basic breeding data regarding the nests of the three radio-tracked male owls (Eurasian pygmy owl, boreal owl and tawny owl) and information regarding their home range sizes recorded during the breeding season 2022. The dates of nesting, hatching and fledging, clutch sizes, numbers of hatchlings and fledglings, parent male owl's age and body mass, numbers of diurnal roosting and nocturnal hunting locations recorded during the monitoring, home range sizes established using the 50%, 90% and 95% Kernel Density Estimation (KDE) and 100% Minimum Convex Polygon (MCP) methods, and the weight of the radio-transmitters used in the study are provided.
Tab. 1. Základné údaje o hniezdení troch rádiom sledovaných samcov sov (kuvička vrbáčieho, pôtika kapcavého a sovy lesnej) a informácie o veľkosti ich domovského okrsku zaznamenané počas hniezdnej sezóny 2022. Uvádzame dátumy hniezdenia, vyliahnutia a vyletenia, veľkosti znášok, počty vyliahnutých a vyletených mláďat, vek a telesnú hmotnosť rodičovského samca, počty lokalizácií denného odpočinku a nočného lovu počas monitorovania, veľkosti domovského okrsku stanovené pomocou metód 50 %, 90 % a 95 % Kernel Density Estimation (KDE) a 100 % Minimum Convex Polygon (MCP) a hmotnosť rádiových vysielačov použitých v štúdiu.

	pygmy owl	boreal owl	tawny owl
Date of nesting*	7 April	21 March	5 March
Date of hatching*	11 May	25 April	7 April
Date of fledging*	9 June	30 May	11 May
No. of eggs	5	5	2
No. of hatchlings	5	3	2
No. of fledglings	5	3	2
Male's age (years)	1+	3+	2
Male's weight (g)	58	101	413
No. of roosting locations	30**	44	38
Roosting KDE 50% (ha)	23.3	23.6	1.4
Roosting KDE 90% (ha)	88.6	92.1	5.5
Roosting KDE 95% (ha)	111.1	116.5	7.1
Roosting MCP 100% (ha)	43.5	343.8	9.1
No. of hunting locations	91	175	210
Hunting KDE 95% (ha)	106.6	155.3	260.3
Hunting MCP 100% (ha)	74.5	128.9	224.2
Radio transmitter weight (g)	1.7	2.9	3.6

*The stated dates of egg-laying, hatching and fledging starts are the best possible estimates (± 2 days).

**The Eurasian pygmy owl male's roosting location was identified 16 times by homing in and 14 times by triangulation.

were collected throughout the tracking period from 6 AM to 9 PM by the homing-in method (Kenward 2001), in which the signal was followed to a particular tree or until the individual was observed. Owl males' locations were recorded using handheld GPS receivers (Garmin GPSmap 60CSx or Astro 230, Garmin Ltd., USA). For the pygmy owl male, roosting locations were also considered to be the fixes recorded at the beginning and the end of the hunting period from which the individual had not moved or had already stopped moving. These roosting locations were recorded using triangulation as all the hunting fixes. The details of the nocturnal hunting data collection methodology are described in Stehlíková Sovadinová et al. (2025).

Although we were unable to capture, radio-tag and monitor the eagle-owl male due to the reasons given above, we decided to include the eagle-owl pair/male in the study due to the pivotal role of the species as an apex predator that exerts a significant influence on the behaviour of other subordinate owl species (e.g., Sergio et al. 2007; Solonen 2011). This decision was further supported and justified by the fact that the vocalisation of the eagle-owl pair/male continued to be recorded throughout the study, confirming their ongoing presence at the study site.

Recording owl vocal activities within the study area is done by voice recorders every spring. Based on the analysis of individual spectrograms (e.g., Galeotti and Pavan 1991; Grava et al. 2008), all the males studied by radio-telemetry almost certainly inhabited the study area at least from 2021. Thus, each male's space use within the study area most probably reflected and was adapted to the presence of all other intraguild species/individuals.

Diet Composition

The composition of the owls' diet was, in the case of boreal and tawny owls, determined by analysing pellets collected at the males' diurnal roosting places and by examining leftover nesting material taken from the nest-boxes after breeding; in the case of pygmy owl, material collected around and in the close vicinity of the breeding cavity was analysed. The pellets and nesting material were soaked in a 5% sodium hydroxide (NaOH) solution to dissolve all undigested prey remains, leaving only the bones intact. The osteological material was then used to identify the prey species by comparing the samples with reference collections (for more details, see Obuch 2001; 2011; 2021). Prey species with a significant deviation from the mean are indicated by additional numbers in front of the count of individuals on a scale of 2– to 1+.

This significant deviation from the mean is calculated as the difference between real abundances (real number of prey species) and theoretical abundances, which is a value obtained from the real and relative representations of elements. Elements with significant deviations from the mean are considered diagnostic (Obuch 2001). Food niche overlap was measured using Pianka's index ($O_{jk} = \sum p_{ij} p_{ik} / \sqrt{\sum p_{ij}^2 p_{ik}^2}$, where p_i is the proportion of prey item "i" in the diet of species "j" and "k") (Pianka 1973). Pianka's index ranges from 0 (total separation) to 1 (total overlap).

Spatial Data Evaluation

All the spatial data, i.e., the distances between the nests of the individual study species, the distances among diurnal roosting locations and nocturnal hunting fixes from their nests and those of other owls, and the diurnal and nocturnal home range shapes and sizes and their mutual overlaps, were evaluated and calculated using ArcGIS 10.5 software (Esri, Redlands, U.S.A.). Individual home ranges were established using Home Range Tools (Rodgers et al. 2007; Rodgers and Kie 2011), a freeware extension for ArcGIS. The home ranges of diurnal roosting and nocturnal hunting for each radio-tracked male were calculated based on all recorded locations/fixes using the 100% Minimum Convex Polygon method (MCP; Mohr 1947; Hayne 1949) and 50%, 90%, and 95% Kernel Density Estimation method (KDE; Silverman 1986; Worton 1989) with fixed smoothing parameter h established by the Least Squares Cross-Validation method (LSCV; Seaman and Powell 1996; Seaman et al. 1999; Börger et al. 2006). The diurnal roosting home range overlaps were calculated using the procedure described by Sonnerud et al. (1986) only for those established by the 95% KDE method.

Results

During monitoring, 37 ± 6 (mean \pm SD) locations of diurnal roosting were recorded for the three owl males. The smallest diurnal roosting home range, 7 ha, established by the 95% KDE method, was recorded for the tawny owl male, while range sizes of 117 and 111 ha were recorded for the boreal and pygmy owl males, respectively (Fig. 1). The home range sizes calculated using other methods, including further details, are given in Table 1.

The joint total overlap of the three monitored males' diurnal roosting home ranges (95% KDE) was 0.3%. The largest roosting home range overlap of 55.2% was recorded for the boreal and pygmy owl males; the overlaps of their roosting ranges with that of the tawny owl male were 1.7% and 3.7%, respectively.

Tab. 2. The owls' nest distances. The individual between-nest distances of the three radio-tracked males (Eurasian pygmy owl, boreal owl and tawny owl), including the nest of eagle-owl pair, and mean (\pm standard deviation) and minimum and maximum (range) distances of the three tracked males' nocturnal hunting fixes and diurnal roosting locations from their own and other owl's nests.

Tab. 2. Vzdialenosti hniezd sov. Individuálne vzdialenosti medzi hniezdami troch rádiovo sledovaných samcov (kuvička vrabčieho, pôtika kapcavého a sovy lesnej) vrátane hniezda páru výra skalného a priemerné (\pm smerodajná odchýlka) a minimálne a maximálne (rozsah) vzdialenosti nočných loveckých a denných odpočinkových lokalizácií troch sledovaných samcov od ich vlastných a ostatných hniezd.

Nest	Distance of pygmy owl nest		Distance of boreal owl nest		Distance of tawny owl nest	
boreal owl	900		-		-	
tawny owl	1266		558		-	
eagle-owl	250		872		1323	
Nest	Distance of pygmy owl roosting locations (n = 30)		Distance of boreal owl roosting locations (n = 44)		Distance of tawny owl roosting locations (n = 37)	
	range	mean \pm SD	range	mean \pm SD	range	mean \pm SD
pygmy owl	35–1164	372 \pm 296	34–2066	698 \pm 458	1257–1695	1519 \pm 161
boreal owl	80–1276	717 \pm 285	178–2082	937 \pm 507	498–832	676 \pm 109
tawny owl	162–1721	1034 \pm 382	226–2609	1303 \pm 584	84–965	565 \pm 348
eagle-owl	116–1195	452 \pm 266	118–2024	649 \pm 447	1300–1600	1486 \pm 107
Nest	Distance of pygmy owl hunting locations (n = 91)		Distance of boreal owl hunting locations (n = 175)		Distance of tawny owl hunting locations (n = 210)	
	range	mean \pm SD	range	mean \pm SD	range	mean \pm SD
pygmy owl	16–982	341 \pm 236	56–1251	598 \pm 322	658–2236	1474 \pm 334
boreal owl	80–1472	749 \pm 298	7–1589	569 \pm 417	33–1489	700 \pm 305
tawny owl	284–1943	1089 \pm 341	95–2042	917 \pm 459	17–1478	470 \pm 302
eagle-owl	17–1039	433 \pm 202	50–1253	619 \pm 295	760–2295	1489 \pm 328

The distances among individual nests, along with the mean distances among males' diurnal roosting and nocturnal hunting locations/fixes from other owls' nests, showed that the tawny owl male remained at a considerably greater distance from the eagle-owl's nest compared to the pygmy and boreal owl males. The specific distances are presented in Table 2.

The males of the two smaller owl species (pygmy and boreal owl) primarily hunted in forest interiors and at the forest edges next to the sapling and clear-cut areas, i.e., at inner forest stand edges (overall 85% and 75%, respectively). In contrast, the larger tawny owl male predominantly hunted at the forest edges adjacent to agricultural fields and meadows, i.e., at outer forest stand edges (in 56%). For resting during diurnal roosting, all three monitored males primarily used Norway spruce trees, more specifically 56%, 93%, and 79% for the pygmy, boreal and tawny owl male, respectively. Further details regarding the males' habitat choice for diurnal roosting and nocturnal hunting are provided in Table 3.

The analysis of pellets and leftovers from the nest-

boxes showed that the pygmy owl male hunted during the breeding season mainly passerine birds. In contrast, the boreal owl male focused primarily on hunting small mammals, predominantly common shrews (*Sorex araneus*) and yellow-necked mice (*Apodemus flavicollis*). The diet of the tawny owl male was relatively diverse and included mammals, birds, amphibians, reptiles and even fish. The species hunted most frequently by the tawny owl male were the common vole (*Microtus arvalis*) and the Eurasian water shrew (*Neomys fodiens*) (Table 4). The overlap of food niches ranged from 0.1 (for the boreal and tawny owl males) through 0.35 (for the pygmy and boreal owl males) to the highest value of 0.4 (for the pygmy and tawny owl males).

Discussion

We found the tawny owl male roosted during the day at a respectful distance from the eagle-owl's nest site in all cases. In contrast, the eagle-owl nest site was included within the diurnal roosting home ranges of smaller owl species, the pygmy and boreal owl. These results on space arrangements of roosting home ranges of the three

Tab. 3. Owls' habitat choice. The roosting places (tree species or nest-box) used for diurnal resting and composition of habitats used during the nocturnal hunting (based on KDE 95% home ranges) by the three radio-tracked male owls (Eurasian pygmy owl, boreal owl, and tawny owl) during the breeding season. The proportion of used roosting sites (%) and their observed numbers in particular places, as well as the proportion of habitats (%) and their areas in hectares used during hunting, are given for each male. **Tab. 3.** Výber biotopov sovami. Miesta odpočinku (druhy stromov alebo hniezdna búdka) využívané na denný odpočinok a zloženie biotopov využívaných počas nočného lovu (na základe KDE 95 % domovských okrskov) tromi rádiovo sledovanými samcami sov (kuvička vrabčieho, pôtika kapcavého a sovy lesnej) počas hniezdného obdobia. Pre každého samca je uvedený podiel využívaných odpočinkových miest (%) a ich pozorovaný počet na jednotlivých miestach, ako aj podiel biotopov (%) a ich plochy v hektároch využívaných počas lovu.

	pygmy owl	boreal owl	tawny owl
Habitat choice during diurnal roosting (number of locations)			
Norway spruce (<i>Picea abies</i>)	56.1% (9)	93.1% (41)	78.9% (30)
Scots pine (<i>Pinus sylvestris</i>)	31.3% (5)	-	-
European beech (<i>Fagus sylvatica</i>)	-	-	15.8% (6)
common alder (<i>Alnus glutinosa</i>)	6.3% (1)	-	-
European larch (<i>Larix decidua</i>)	6.3% (1)	2.3% (1)	-
silver fir (<i>Abies alba</i>)	-	2.3% (1)	-
sycamore (<i>Acer pseudoplatanus</i>)	-	2.3% (1)	-
empty nest-box	-	-	5.3% (2)
Habitat choice during nocturnal hunting (area in hectares)			
Norway spruce dominated forest stands	50.5% (54)	45.8% (71)	24.6% (64)
deciduous trees dominated forest stands	6.5% (7)	6.5% (10)	7.3% (19)
sapling and clear-cut areas	28.0% (30)	22.6% (35)	11.9% (31)
agricultural fields and meadows (forest edges)	15.0% (16)	25.1% (39)	56.2% (146)

studied owl males concerning the eagle-owl's nest site fit the previous findings on their hunting home ranges (Stehlíková Sovadinová et al. 2025). The pygmy and boreal owl male hunting range overlapped by 78%; in contrast, their hunting ranges overlapped with that of the tawny owl male only by 15% and 25%, respectively. Similar to the currently described roosting ranges, the tawny owl's hunting range was situated at an apparent distance from the eagle-owl's nest site compared to the hunting ranges of the two smaller owl species that both contained it (Stehlíková Sovadinová et al. 2025). Thus, the roosting home range space arrangements align with and support our previous conclusions that medium-sized owl species may avoid areas occupied by apex intraguild predator/s (Stehlíková Sovadinová et al. 2025). In contrast, the small owl species may use the apex intraguild predator/s for their protection, likely because they do not represent suitable prey. Thus, apex intraguild predator/s may indirectly create a "protective umbrella" effect, providing refugia free from medium-intraguild enemies for the smaller species (Stehlíková Sovadinová et al. 2025).

The fact that the pygmy and boreal owl males had

almost identical diurnal roosting home ranges (Fig. 1) and nocturnal hunting home ranges (Stehlíková Sovadinová et al. 2025), too, and shared their environment so closely, although they also are intraguild enemies, is fascinating. On the other hand, they pose only a minor threat to each other, and attacks by boreal owl on pygmy owl have been observed only very rarely (Mikkola 1983; Korpimäki and Hakkarainen 2012). The very close spatiotemporal sharing of the environment by boreal and pygmy owls is probably enabled by their different dietary preferences during the breeding season (Korpimäki and Hakkarainen 2012; Šotnár et al. 2015). This was also reflected in our analysis of the owls' diets, confirming that boreal owl is a food specialist focusing on voles (Korpimäki and Hakkarainen 2012), while the primary prey of the pygmy owl during breeding consists of passerine birds (Mikusek et al. 2001). Moreover, there is temporal segregation within the hunting activities of the two species because boreal owls hunt exclusively at night (Korpimäki 1981), while pygmy owls are a crepuscular species (Mikkola 1983; Pačenovský and Šotnár 2010). Lastly, our findings regarding the closely shared home range areas of the two petite owl

Tab. 4. The diet composition of the Eurasian pygmy owls, boreal owls and tawny owls collected in Křížanovská vrchovina (the Krizanov Highlands), Vysočina region, Czechia, in the year 2022, and expressed by the count of individuals found in pellets or leftover nesting materials (see Materials and Methods for methodological details).

Tab. 4. Zloženie potravy kúvička vrbčieho, pôtika kapcavého a sovy lesnej zozbieranej na Křížanovskej vrchovine v kraji Vysočina v Česku v roku 2022 a vyjadrené počtom jedincov nájdených vo vývržkoch alebo zvyškoch hniezdneho materiálu (pre viac podrobností pozri Materials and Methods).

Species	pygmy owl				boreal owl				tawny owl		Total	%	
	natural cavity	roosting place		natural cavity	roosting place		natural cavity	roosting place					
<i>Talpa europaea</i>								2	1	3	0.73		
<i>Sorex araneus</i>	2-	0	1-	0	1+	52	1	50	1-	25	128	31.7	
<i>Sorex minutus</i>		1				1	1	2	1+	11	16	3.88	
<i>Neomys milleri</i>										1	1	0.24	
<i>Neomys fodiens</i>		1						1+	10	3	14	3.40	
<i>Crocidura leucodon</i>										1	1	0.24	
<i>Lepus europaeus</i>										1	1	0.24	
<i>Muscardinus avellanarius</i>					4		1	4		5	14	3.40	
<i>Micromys minutus</i>							1			2	3	0.73	
<i>Apodemus flavicollis</i>		4		1	1+	25	3	1-	8	18	59	14.32	
<i>Apodemus sylvaticus</i>				1		1	1			12	8	23	5.58
<i>Clethrionomys glareolus</i>	1+	8		2		9	5		17	1-	5	46	11.17
<i>Arvicola amphibius</i>									3		3	0.73	
<i>Microtus subterraneus</i>											1	1	0.24
<i>Microtus arvalis</i>				3	2-	0	1		13	1+	21	38	9.22
<i>Microtus agrestis</i>				4							1	5	1.21
<i>Sylvia communis</i>									1		1	0.24	
<i>Sylvia atricapilla</i>		1									1	0.24	
<i>Phylloscopus trochilus</i>											1	1	0.24
<i>Regulus</i> sp.		1					1				2	0.49	
<i>Erithacus rubecula</i>		1		1					1		3	0.73	
<i>Turdus merula</i>									3	3	6	1.46	
<i>Turdus pilaris</i>									3		3	0.73	
<i>Turdus iliacus</i>										1	1	0.24	
<i>Turdus philomelos</i>									1	2	3	0.73	
<i>Turdus viscivorus</i>									1	1	2	0.49	
<i>Aegithalos caudatus</i>		1									1	0.24	
<i>Parus major</i>		1									1	0.24	
<i>Periparus ater</i>				1							1	0.24	
<i>Cyanistes caeruleus</i>		1									1	0.24	
<i>Poecile palustris</i>		3									3	0.73	
<i>Sitta europaea</i>				1							1	0.24	
<i>Certhia</i> sp.		1									1	0.24	
<i>Emberiza citrinella</i>									1		1	0.24	
<i>Fringilla coelebs</i>									1	2	3	0.73	
<i>Loxia curvirostra</i>		1									1	0.24	
<i>Garrulus glandarius</i>									1	1	2	0.49	
Passeriformes sp.		1									1	0.24	
Passeriformes sp. juv						1					1	0.24	
<i>Rana temporaria</i>									7	2	9	2.18	
<i>Zootoca vivipara</i>										1	1	0.24	
Serpentes sp.									1		1	0.24	
Cypriniformes sp.										2	2	0.49	
Coleoptera sp.									2		2	0.49	
Mammalia	1-	14		11		92	14	121		104	356	86.41	
Aves	1+	12		3	1-	1	1	13		11	41	9.95	
Amphibia, Reptilia, Pisces		0		0		0	0	8		5	13	3.16	
Evertebrata		0		0		0	0	2		0	2	0.49	
Total		26		14		93	15	144		120	412	100	
Diversity index H'		2.28		1.91		1.19	1.95	2.33		2.55	2.53		

species align with observations that pygmy owls did not spatially avoid boreal owls even though the presence of the latter species can exert a negative influence on the reproductive success of pygmy owls (Morosinotto et al. 2017).

The roosting ranges (95% KDE) of the two smaller owl species males were of comparable size, which was also the case for their hunting ranges. In contrast, the male tawny owl's roosting range was tiny, approximately 16 times smaller than the pygmy and boreal owl roosting ranges and around 40 times smaller than his hunting range. This difference is hard to explain, but we can speculate that it was due to habitat composition and the individual's preference for roosting in specific forest stands. The tawny owl male used roosts exclusively in two small patches near his nest-box, invariably in the very dense treetops of relatively young mixed spruces and beeches. The male likely returned regularly to familiar and safe locations where he could hide perfectly during the day, a presumption which aligns with findings that tawny owls avoid roost sites where they have been mobbed in the past (Flasskamp 1994), preferring instead sites which offer protection against avian predators and mobbers (Sunde et al. 2003).

The male owls' hunting home range sizes recorded during the breeding season (snap-trapping at the study site revealed prey abundance of 4.2 small mammals captured per 100 trap-nights) are comparable with those reported previously for all three study species. For example, different studies have recorded pygmy owls' mean hunting home range sizes of 67 ha (Barbaro et al. 2016), 95 ha (Baroni 2022) and 173 ha (Rothgänger 2023), while research from Norway has identified pygmy owls' ranges around three times larger than those in our study (median = 230 ha), but they monitored pygmy owls also during the non-breeding seasons and in the low phase of the vole cycle (Strøm and Sonerud 2001). The difference between these and our results can be explained by the fact that we tracked the male pygmy owl during the breeding season only, moreover with high prey abundance, and it is widely known that high abundances of prey species can negatively affect hunting home range sizes (Kouba et al. 2017). Regarding tawny owls, our findings match the mean hunting home ranges of 196 ha (Burgos and Zuberogoitia 2020) and 213 ha (Choi et al. 2020) recorded in other studies. The hunting home ranges of boreal owls have also been studied, including two studies from Czechia. The mean home range size recorded during the breeding season in the Ore Mts. was 191 ha (Kouba et al. 2017), while the

ranges of two males from the Jizera Mts. covered an area of 310 ha (Kouba and Tomášek 2018). The findings of the first study are clearly closer to those of our research, while the ranges observed in the second study are two times larger.

The sizes of diurnal roosting home ranges were not correlated with the study species' weight (i.e., the body mass of the tracked individuals). This finding is not consistent with the 'body weight hypothesis', which posits that larger species inhabit more spacious home ranges because the overall higher energy needs for themselves and their offspring require them to hunt in larger areas (Harestad and Bunnell 1979; Saiful et al. 2001; Ottaviani et al. 2006). Unlike the diurnal home ranges, the sizes of nocturnal hunting ones correlated positively with the study species' weight. These findings demonstrate that very different factors determine the sizes of roosting compared to hunting home ranges. In this context, however, it is essential to note that the hunting home ranges of the nesting male owls are also influenced by other external factors, such as prey abundance and the number of fledglings (Campioni et al. 2013; Kouba et al. 2017). However, because the three owl males were tracked under the same circumstances and inhabited the same spatiotemporal environment, thereby exposing them to identical external influences, it is possible to suggest that the species' body mass is one of the decisive factors determining their hunting home range size.

This study provides new insights into the three jointly examined aspects: the sizes and spatial arrangements of diurnal roosting home ranges, diet composition, and roosting sites of males of three owl species, the pygmy, boreal and tawny owl, during the breeding season within the area of sympatry also inhabited by an apex intraguild predator, the eagle-owl. The results of this study indicate that intraguild competitors/enemies may mitigate direct conflict through spatial avoidance and dietary differentiation. This partial niche separation may help to reduce food competition within the guild, promoting coexistence among species.

In conclusion, however, we acknowledge the limitations of our case report study. Our sample size is undoubtedly limited, and the study results should be taken as preliminary and not generalised. Finally, we encourage researchers to employ similar study designs to investigate interactions among multiple sympatric intraguild species under identical spatiotemporal conditions, as this topic has been considerably understudied to date.

Ethics Approval

Owl males were trapped, handled and tagged under Permit No. ŽP/163/2020-chme /351/2020 issued by the Ministry of the Environment of the Czech Republic and ringed under the supervision of the Ringing Centre of the National Museum in Prague, Permit No. 1172.

Data Availability

The raw data supporting this article are available from the corresponding author upon reasonable request.

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The helminth fauna of the Eurasian goshawk (*Accipiter gentilis*) in northwest Russia

Fauna helmintov jastraba veľkého (*Accipiter gentilis*) na severozápade Ruska

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Abstract: The challenges in researching the parasite fauna of rare and red-listed species, such as the Eurasian goshawk (*Accipiter gentilis*), render the study of accidental findings of these birds highly valuable and important. This paper discusses the results regarding the species diversity and occurrence of helminths in the Eurasian goshawk in northwest Russia. In July and September 2024, parasites were collected from the respiratory and gastrointestinal tracts of two birds that had died in the City of Petrozavodsk and the Village of Porosozero. This is the first report of the occurrence of nine helminth species (trematodes *Neodiplostomum attenuatum*, *Srtigea falconis*, *Prosthogonimus cuneatus* and nematodes *Cyathostoma americana*, *Eucoleus dispar*, *Porrocaecum depressum*, *Baruscapillaria falconis*, *Capillaria tenuissima*, *Microtetrameres* sp.) in the Eurasian goshawk, which is actively expanding its distribution in northwest Russia. Karelia is the only region where the trematode *P. cuneatus* has been found in the Eurasian goshawk. With the new findings, we provide an overview of Eurasian goshawk's parasite fauna, with reference to available information on other regions of Russia and Europe. A list of 43 helminth species documented for hawks has been compiled using published data. Another important outcome of our study is that, having analysed the birds, we managed to describe the ecological characteristics of the birds adapting to urbanised environments (cities and rural communities). This adaptation likely involves changes in the birds' dietary spectrum and, accordingly, the species composition and infection rates of their common helminth parasites.

Abstrakt: Pri výskume parazitofauny vzácných druhov a druhov uvedených v červenom zozname, ako je jastrab veľký (*Accipiter gentilis*), sú náhodné nálezy týchto vtákov veľmi cenným a dôležitým zdrojom údajov. Príspevok prináša výsledky týkajúce sa druhovej diverzity a výskytu helmintov u jastraba veľkého v severozápadnom Rusku. V júli a septembri 2024 boli parazity odobraté z dýchacích a gastrointestinálnych ciest dvoch vtákov, ktoré uhynuli v meste Petrozavodsk a obci Porosozero. Toto je prvá správa o výskyte deviatich druhov helmintov (motolice *Neodiplostomum attenuatum*, *Srtigea falconis*, *Prosthogonimus cuneatus* a hlístovce *Cyathostoma americana*, *Eucoleus dispar*, *Porrocaecum depressum*, *Baruscapillaria falconis*, *Capillaria tenuissima*, *Microtetrameres* sp.) u jastraba veľkého, ktorý aktívne zvažuje svoje rozšírenie v severozápadnom Rusku. Karélia je jediný región, kde sa u jastraba veľkého zistila motolice *P. cuneatus*. Vďaka novým zisteniam poskytujeme prehľad parazitickej fauny jastraba veľkého s odkazom na dostupné informácie o iných regiónoch Ruska a Európy. Na základe publikovaných údajov bol zostavený zoznam 43 druhov helmintov zdokumentovaných u jastrabov. Ďalším dôležitým výsledkom našej štúdie je, že po analýze vtákov sa nám podarilo opísať ekologické charakteristiky vtákov adaptujúcich sa na urbanizované prostredie (mestá a vidiecke komunity). Táto adaptácia pravdepodobne zahŕňa zmeny v stravovacom spektre vtákov a podľa toho aj v druhovom zložení a miere infekcie ich bežnými helmintovými parazitmi.

Key words: parasitic communities, trematodes, nematodes, Accipitridae, bird of prey, urbanisation, Karelia

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Introduction

Birds of prey are a crucial component of natural communities. They occupy a special place in scientific research as model objects in studying fundamental ecology questions and as indicators of environmental change. The helminth fauna of raptors is shaped by multiple abiotic and biotic factors, among which dietary patterns play a leading role. The invertebrate and vertebrate species that raptors feed on act as intermediate helminth hosts. The habitat use and dietary behaviours of birds are essential for realising helminth life cycles. That is why studying their parasite fauna is of great interest to science. However, most of the data available are accidental and single findings. Few papers deal with parasites hosted by raptors in Russian Karelia or northwest Russia in general. For instance, data on the parasite fauna of an osprey (*Pandion haliaetus*) found dead at a trout farm in Karelia (Lake Ladoga), obtained for the first time using both molecular and morphological methods, have resulted in the identification and description of a trematode species, *Nematostrigea serpens*, new for Karelia (Lebedeva et al. 2013; Lebedeva & Yakovleva 2016). This fluke is an obligate parasite of the osprey, but it also sometimes occurs in other predatory and piscivorous birds. The life cycle of this trematode is poorly known and involves fish as intermediate hosts (Zhokhov & Mishina 2011).

The Eurasian goshawk is the largest species in the *Accipiter* genus, with a body up to 56-58 cm long, a wingspan of 105-127 cm, and a weight of 1.2-2 kg. The species is widespread throughout the forest zone of Eurasia and North America, as well as in the forest-tundra and forest-steppe. In Russia, the goshawk nests from the western borders to Kamchatka, Kuril Islands and Sakhalin. Its numbers have been growing, the distribution has expanded, and encounters in urban parks and forests have been reported (Stepanyan 2003, Noskov et al. 2016). The Eurasian sparrowhawk (*Accipiter nisus*) and the Eurasian goshawk leave Karelian forests for the winter, but some birds stay, settling near farms and preying on small birds and corvids (Neufeldt 2019, Tolstoguzov et al. 2022). The factors determining the species diversity of helminths in this raptor are their diet and the prey diversity and availability.

There is diverse data in the literature on the parasite fauna of hawks, but most of these papers are reports on certain species with descriptions of the parasites found in either captive (in aviaries) or wild birds. Eurasian goshawks have been best studied in Central Europe: in the Czech Republic and Slovakia (Komorová et al. 2016; Sitko 2011; Sitko & Okulewicz 2010; Sitko et al.

2006), Spain (Sanmartín et al. 2004; Ferrer et al. 2004), Italy (Santoro et al. 2012), Greece (Papazahariadou et al. 2008), and Germany (Krone 2000). In Russia, the greatest number of Eurasian goshawk individuals (20 birds) have been examined for helminths by full dissection at rehabilitation facilities and animal clinics of Moscow City, Moscow and Tula Regions (Dorohov & Davydova 2020). The goshawks were found to host eight species: two trematode species (*Neodiplostomum attenuatum*, *Strigea falconis*) and six nematode species (*Cyathostoma americana*, *Physaloptera apivori*, *Porrocaecum angusticolle*, *P. depressum*, *Capillaria tenuissima*, *Baruscapillaria falconis*). Singular birds have been examined in central parts of Bashkortostan (Valuev 2010), where a female Eurasian goshawk contained three helminth species – *Porrocaecum depressum*, *Strigea falconis*, and *Neodiplostomum cochleare*, one specimen each. Another type of data available is the results obtained by coprological methods (Mailyan 2003, Davydova et al. 2016, Dorokhov 2021, Kravchenko et al. 2023). Eurasian goshawks have been studied alongside other birds of prey in several aviaries by sampling droppings for analysis. This method is ineffective in fully revealing the species diversity of helminths in birds.

This paper presents the first study of the helminth fauna of the Eurasian goshawk in urbanised areas of Karelia, northwest Russia.

Material and methods

In July and September 2024, two cadavers of the Eurasian goshawk specimens were received from residents of the City of Petrozavodsk (61.79° N, 34.38° E) and the Village of Porosozero (62.71° N, 32.70° E) of the Suojarvi District, located 135 km north of Petrozavodsk. Both birds were found dead (Fig. 1) and were later examined by the full helminthological dissection method. They were young, first-year male and female. The collection of parasitological samples, fixation and ex-situ treatment followed standard techniques (Dubinina 1971). The birds' digestive tract and organs (stomach, heart, liver, kidneys, lungs, trachea, bursa of Fabricius) were examined for helminths. Helminth identification was based on keys and original descriptions (Baruš et al. 1978, Sonin 1985, 1986, Sonin & Barush 1996, Oyarzún-Ruiz et al. 2024). After identifying and counting the helminths retrieved, the quantitative parameters of the infection were calculated. The morphology of the parasites was studied using the Olympus BX-53 microscope with the DIC option (equipment provided by the Core Facility of the Karelian Research Centre RAS, Petrozavodsk, Russia).

Fig. 1. Schematic map of sampling sites in northwest Russia: 1 – City of Petrozavodsk, 2 – Village of Porosozero.

Obr. 1. Schematická mapa miest odberu vzoriek v severozápadnom Rusku: 1 – mesto Petrozavodsk, 2 – dedina Porosozero.



Results

The two goshawk specimens in our study contained nine helminth species (Table 1). The first specimen (from the city) hosted seven species, and the second one (from the village) had five species. The trematodes *Neodiplostomum attenuatum* and *Strigea falconis* (Fig. 2) and the nematodes *Baruscapillaria falconis*, *Capillaria tenuissima*, *Cyathostoma americana*, *Eucoleus dispar*, *Microtetrameres* sp., *Porrocaecum depressum* are the first records for Karelia. The trematode *Prosthogonimus cuneatus* is, for the first time, reported for the new host, the Eurasian goshawk (Fig. 3). The morphological traits and dimensions of helminths in our samples match those in the Keys (Baruš et al. 1978, Sonin 1985, 1986, Sonin & Barush 1996, Oyarzún-Ruiz et al. 2024), so we omitted the measurements.

Among the nine species found (Table 1), only three were shared by the two birds – the trematode *S. falconis*, infecting the birds at similar intensities (10 and 8 worms), and two nematode species – *C. americana* (Fig. 4), which was more abundant in the bird from the village (64 vs 16 worms), and *P. depressum*, also with a higher infection rate in the bird from the village (19 worms) than in the one from the city (10 worms). The trematodes *N. attenuatum* and *P. cuneatus* and two nematode species, *B. falconis* and

Eucoleus dispar, were found only in the goshawk picked up in the city (Table 1). Three of the above species were found as singular specimens. Only *B. falconis* showed a relatively high infection intensity (Table 1). The bird from the village specifically featured two nematodes – *C. tenuissima* and *Microtetrameres* sp., represented by nine and four specimens, respectively.

Having assembled the available published data, we compiled a list of 43 species of helminths documented from hawks (Table 2), including nematodes (24 species), trematodes (12 species), cestodes (5 species), and acanthocephalans (2 species).

Discussion

The helminths found in the two examined goshawks have a complex life cycle involving obligatory intermediate and reservoir hosts, ensuring the successful completion of the parasite's life cycle. For instance, the life cycle of the nematode *Cyathostoma americana* has not been studied, but inferring by analogy with the related species, it likely uses earthworms as intermediate hosts, and probable supplementary hosts are small mammals, which can transmit the nematodes to the raptors that prey on them (Fernando & Barta 2008). The infection with the nematode *Porrocaecum depressum* in the birds

Tab. 1. Species composition of helminths found in the two Eurasian goshawk cadavers from northwest Russia (Karelia).

Tab. 1. Druhové zloženie helmintov nájdených v dvoch mŕtvych telách jastraba veľkého zo severozápadného Ruska (Karelia).

Parasite group	Parasite species	Localization	Number of helminths, ind.	
			female bird, City of Petrozavodsk	male bird, Village of Porosozero
Trematoda	<i>Neodiplostomum attenuatum</i>	small intestine	1	–
	<i>Prosthogonimus cuneatus</i>	bursa of Fabricius	3	–
	<i>Strigea falconis</i>	duodenum, small intestine	10	8
	<i>Baruscapillaria falconis</i>	small intestine	15	–
	<i>Capillaria tenuissima</i>	small intestine, oral cavity	–	9
Nematoda	<i>Cyathostoma americana</i>	lungs, trachea, airways, nasal cavity	16	64
	<i>Eucoleus dispar</i>	esophagus	1	–
	<i>Microtetrameres</i> sp.	glandular stomach	–	4
	<i>Porrocaecum depressum</i>	small intestine	10	19
Total			7	5

examined is also presumably associated with the fact that the reservoir hosts in the life cycle of these nematodes are earthworms and small mammals (Hartwich 1975). For the rest of the nematodes (*Eucoleus dispar*, *Baruscapillaria falconis*, *Capillaria tenuissima*), the presumed main pathway for infecting raptors is through the consumed gulls, crows, and partridges, which had ingested nematode-infected earthworms (Heidenreich 1997).

The *Microtetrameres* sp. nematodes in our samples were females, making identification down to species impossible. The available data suggest that their life cycle may include insects of the order Orthoptera (Anderson 2000) and beetles of the Tenebrionidae or Blattidae families as intermediate hosts (Schell 1953). The reservoir host is passerines whose diet includes insects (Kirillov et al. 2018). Goshawks are invaded by these nematodes when consuming infected passerine birds.



Fig. 2. Microphotograph of *Strigea falconis* found in a Eurasian goshawk from northwest Russia. Scale bar 0.5 mm.

Obr. 2. Mikrofotografia *Strigea falconis* nájdená v jastrabovi veľkom zo severozápadného Ruska. Mierka 0,5 mm.

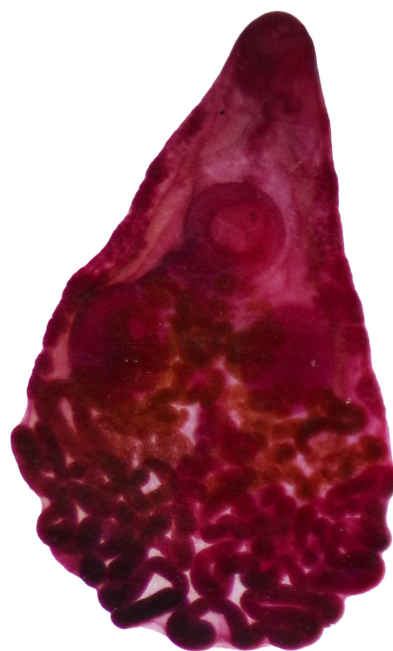


Fig. 3. Microphotograph of *Prosthogonimus cuneatus* found in a Eurasian goshawk from northwest Russia. Scale bar 1 mm.

Obr. 3. Mikrofotografia *Prosthogonimus cuneatus* nájdená v jastrabovi veľkom zo severozápadného Ruska. Mierka 1 mm.

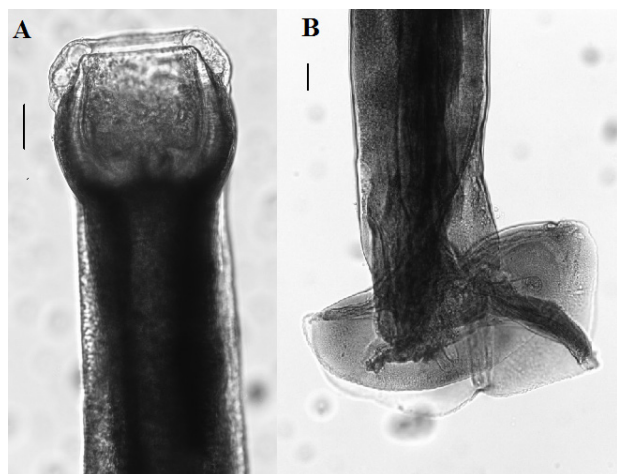


Fig 4. Microphotograph of a male *Cyathostoma americana* from Eurasian goshawk from northwest Russia: anterior region (A) and posterior region (B). Scale bar 0.05 mm.

Obr. 4. Mikrofotografia samca *Cyathostoma americana* z jastraba veľkého zo severozápadného Ruska: predná časť (A) a zadná časť (B). Mierka 0,05 mm.

The trematodes retrieved from the examined goshawk individuals belong to three species – *Neodiplostomum attenuatum*, *Prosthogonimus cuneatus* and *Strigea falconis*. The life cycle of *S. falconis* involves gastropods as the first intermediate host. The second intermediate (reservoir) host options include amphibians, reptiles, birds and small mammals (Odening 1967), preying on which appears to be the pathway for infecting goshawks. The other two species were found only in the bird from Petrozavodsk. The life cycle of the trematode *Neodiplostomum attenuatum* involves amphibians and reptiles, which act as reservoir hosts for this parasite (Odening 1965). *Prosthogonimus cuneatus* was also retrieved from the goshawk found in the city. This fluke species has previously been reported for Anatidae and the Eurasian Coot (Yakovleva 2013). Its first intermediate hosts are gastropods of the genera *Bythynia* and *Gyraulus*. Second intermediate hosts are larvae and imagoes of Odonata genera *Libellula* Linnaeus, 1758, *Aeschna* Fabricius, 1775, *Anax* Leach, 1815, *Sympetrum* Newman, 1833, etc., mayflies and caddis flies (Panin 1957, Sharpilo & Iskova 1989). Attacks on waterfowl, especially ducklings, are a likely pathway to goshawk infestation with *Prosthogonimus cuneatus*.

In Karelia, the hawk genus (*Accipiter* Brisson, 1760) is represented by two species – the Eurasian sparrowhawk and the Eurasian goshawk. According to the literature, the hawks studied in the Czech Republic

and Slovakia feature the highest parasite species richness (Table 2). In these countries, the parasite fauna has been studied in different raptor species of the orders Accipitriformes, Falconiformes, and Strigiformes (Sitko et al. 2006, Sitko & Okulewicz 2010, Sitko 2011, Komorová et al. 2016). The general helminth diversity in birds from Central Europe is relatively high (Table 2). It is specifically worth mentioning the data on the species richness and diversity of the helminth fauna of captive *Accipiter* birds (Table 2). For instance, Davydova et al. (2016) reported that infection with *Ascaridia* sp. nematodes in sparrowhawks and goshawks in an aviary in the Tula Region could be the result of their diet necessarily including quails (*Coturnix* Garsault, 1764), which are common hosts for ascarids (Mozgovoy 1953). Most of the helminths found in aviary-kept hawks, except for capillarids and ascarids, have a complex life cycle with a change of hosts, suggesting the infestation had taken place in the wild before the birds were removed from their natural habitats (Davydova et al. 2016).

The difference in the helminth fauna of Eurasian goshawks in urbanised areas of Karelia from data in the literature is the absence of cestodes and acanthocephalans. All the helminths found in our study can parasitise other species of raptors as well as hawks (Dorokhov & Davydova 2020). The nematodes *Baruscapillaria falconis*, *Capillaria tenuissima*, *Microtetrameres* sp., and *Eucoleus dispar* have been documented for goshawks (*A. nisus* and *A. gentilis*) in the Czech Republic and Slovakia (Sitko et al. 2006, Sitko & Okulewicz 2010, Sitko 2011, Komorová et al. 2016), Spain (Ferrer et al. 2004, Sanmartín et al. 2004), Italy (Santoro et al. 2012), Greece (Papazahariadou et al. 2008), and Germany (Krone 2000). A curious finding is nematodes of the genus *Microtetrameres*, previously reported for hawks only in Spain (Ferrer et al. 2004, Sanmartín et al. 2004). However, helminths of this genus can also occur in other raptor species (Sitko & Okulewicz 2010). The nematode *Baruscapillaria falconis* is the most frequently encountered parasite of the family Capillariidae in diurnal and nocturnal birds of prey. It has mostly been found in the European part of Russia (Valuev 2010, Dorokhov & Davydova 2020, Kirillov & Kirillova 2017).

A unique finding in our sample is the species *Prosthogonimus cuneatus*. This is the first record for the Eurasian goshawk, both in northwest Russia and Europe. A possible reason for its absence in the literature on raptors is that no young birds have previously been

Tab. 2. The list of helminth species documented from the genus *Accipiter* (*A. nisus*, *A. gentilis*) in Russia and Europe.

Tab. 2. Zoznam druhov helmintov zdokumentovaných z rodu *Accipiter* (*A. nisus*, *A. gentilis*) v Rusku a Európe.

Groups and species of parasites	Russia											
	Our data	Data from various nurseries (1)	Central Russia (2)	Middle Volga region (3)	Lake Baikal catchment area (4)	Bashkortostan (5)	Italy (6)	Spain (7)	Czechia and Slovakia (8)	Netherlands (9)	Greece (10)	Germany (11)
TREMATODA												
<i>Apharyngostrigea flexilis</i>												+
<i>Australapatemon minor</i>									+			
<i>Cotylurus cornutus</i>									+			
<i>Neodiplostomum attenuatum</i>	+	+	+				+	+		+		
<i>N. spathoides</i>									+			+
<i>N. cochleare</i>						+						
<i>Plagiorchis elegans</i>									+			
<i>Prosthogonimus cuneatus</i>	+											
<i>Strigea falconis</i>	+	+	+	+	+	+	+	+	+	+		+
<i>S. strigis</i>					+							
<i>Strigea</i> spp.		+						+				
<i>Tylodelphys excavata</i>									+			
NEMATODA												
<i>Ascaridia galli</i>		+										
<i>Ascaridia</i> sp.		+	+									
<i>Baruscapillaria falconis</i>	+	+	+	+			+		+	+		
<i>Capillaria caudinflata</i>		+										
<i>C. tenuissima</i>	+	+	+					+			+	+
<i>Capillaria</i> sp.		+								+		
<i>Cardiofilaria pavlovskyi</i>												+
<i>Contraecaecum rudolphii</i>									+			
<i>Cyathostoma americana</i>	+		+							+		
<i>Eucoleus dispar</i>	+	+					+	+	+		+	+
<i>Hovorkonema variegatum</i>								+				+
<i>Microtetrameres inermis</i>				+								
<i>Microtetrameres</i> sp.	+							+				
<i>Porrocaecum angusticollae</i>			+				+	+	+	+		
<i>P. depressum</i>	+	+	+	+		+			+	+		
<i>Porrocaecum</i> sp.										+		+
<i>Procymea mansioni</i>							+					+
<i>P. leptoptera</i>								+				
<i>Physaloptera alata</i>		+	+			+	+	+	+	+		+
<i>Physaloptera apivori</i>			+									
<i>Physocephalus sexalatus</i>				+								
<i>Streptocara crassicauda</i>												+
<i>Syngamus trachea</i>			+									
<i>Synhimantus laticeps</i>							+	+	+	+		+
CESTODA												
<i>Cladotaenia globifera</i>			+				+	+				+
<i>Passerilepis passeris</i>							+					
<i>Spiniglans constricta</i> (<i>Pseudanomotaenia constricta</i>)							+					
<i>Mesocestoides perlatus</i>							+					
<i>Dilepis undula</i>							+					
ACANTHOCEPHALA												
<i>Centrorhynchus globocaudatus</i> (<i>Centrorhynchus</i> spp.)							+	+	+	+	+	+
<i>Acantocephala</i> sp.		+										
Total	9	13	12	5	8	4	10	13	16	11	3	13

Note: 1 – Mailyan 2003, 2011, Davydova et al. 2016, Dorokhov 2021, Kravchenko et al. 2023; 2 – Kozlitsin 2018, Dorokhov & Davydova 2020; 3 – Kirillov & Kirillova 2013, 2017, Kirillov et al. 2018; 4 – Nekrasov 2000; 5 – Valuev 2010; 6 – Santoro et al. 2012; 7 – Ferrer et al. 2004, Sanmartín et al. 2004; 8 – Sitko et al. 2006, Sitko & Okulewicz 2010, Sitko 2011, Komorová et al. 2016, 2017; 9 – Borgsteede et al. 2003.; 10 – Papazahariadou et al. 2008; 11 – Krone 2000, Krone et al. 2007.

examined, considering that the primary localisation for this species is the bursa of Fabricius, which atrophies in adult birds. Apparently, the diet of young goshawks includes insectivorous birds since the life cycle of *P. cuneatus* involves insects (Panin 1957, Sharpilo & Iskova 1989).

The Eurasian goshawk individuals studied here provide a ground for describing the ecology of the birds that are beginning to use urbanised habitats. In addition, we summarised and provided a list of available literature on the helminth fauna of Eurasian goshawks in Russia and Europe.

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Ethics approval statement

There are no human or animal studies in this paper that meet the criteria of Directive 2010/63/EU. The birds were found dead.

Conflicts of interest

All authors declare that they have no conflicts of interest.

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The first documentation of a juvenile eastern imperial eagle (*Aquila heliaca*) with an unstreaked body

Prvé zdokumentovanie mlád'at'a orla kráľovského (*Aquila heliaca*) s nežihánym telom

Ivaylo ANGELOV

Abstract: An extremely pale juvenile eastern imperial eagle (*Aquila heliaca*) without the typical dark streaking of the body was observed and photographed wintering in Oman. The bird presented an identification challenge and was initially identified as a tawny eagle (*Aquila rapax*). The possible overlap in the breeding distribution of both species is discussed, together with the possibility for natural hybridisation.

Abstrakt: Mimoriadne bledý mladý orol kráľovský (*Aquila heliaca*) bez typického tmavého žihania na tele bol pozorovaný a odfotografovaný počas zimovania v Ománe. Vták predstavoval výzvu pri určovaní a pôvodne bol identifikovaný ako orol skalný (*Aquila rapax*). V príspevku diskutujeme možné prekrývanie hniezdneho rozšírenia oboch druhov, ako aj o možnosti prirodzenej hybridizácie.

Key words: raptor identification, colouration, colour morph, hybridisation, tawny eagle, Oman, birds of prey

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Introduction

Diurnal raptor species are often difficult to differentiate in the field (Fergusson-Lees & Christie 2001), partly due to a high degree of colour variability; 30% of raptor species show polymorphism (Fowlie & Krüger 2003). The literature on raptor identification is well-developed, and improvements are regularly made, mostly due to the description of new colour morphs and aberrant plumages (Corso & Monterosso 2000, Sternalski et al. 2012).

For some species, it is unclear whether the described individuals are simply rare colour mutations or definable yet rare colour morphs. For example, for the greater spotted eagle (*Clanga clanga*), until very recently, it was not known whether the pale *fulvescens* morph persists into adulthood (Dombrovski 2023).

Material and Methods

On 28 February 2024, I conducted a two-hour count (6:45 – 8:45 AM) of vultures and large eagles at Al Multaqaa landfill, near Muscat, Oman (23.34°N, 58.46°E). The birds were observed with a telescope 20-60x60 and binoculars 10x50. Photographs were made with a digital camera using a 600 mm lens.

Results

A large eagle was initially identified as a tawny eagle, but subsequent scrutiny of the photos challenged this conclusion (Fig. 1). Its size was that of the largest *Aquila* species, and was first photographed displacing a juvenile steppe eagle (*Aquila nipalensis*) perched on the ground. It remained perched and in view for several minutes before



Fig. 1. The eagle in question in different postures (A, B, C). Perching and displacing a steppe eagle while showing its underwing and undertail pattern (A); perching, partially showing the upperwing coverts (B); perched, showing the unstreaked body and pale iris (C).

Obr. 1. Predmetný orol v rôznych polohách (A, B, C). Sediaci a vytlačujúci orola stepného, pričom je viditeľná jeho kresba pod krídlami a pod chvostom (A); sediaci, pričom sú čiastočne viditeľné horné krycie perá (B); sediaci, pričom je viditeľné nežihané telo a bledá dúhovka (C).

taking off and immediately disappearing behind a ridge. It was not seen again.

The eagle was aged as a juvenile by its uniform underwing pattern (Forsman, 2016). It was a very large eagle with a gape that reached the middle of the eye; its iris was pale, its body plumage was of a uniformly light beige, with pale colouration of the throat, chest and belly, without any noticeable streaking, and was the same colour as the undertail and trousers. The lesser and median underwing coverts were of the same light beige colour as the body, while the greater coverts were black with white edges. The underwing primaries had fine, dense barring; the secondaries were similar, but barring extended about 2/3 their length from the base until two-thirds of the secondaries. The upperwing coverts were of the same colour as the body and had fine dark streaking.

Discussion

The large size of the eagle is evident by comparing it to that of the juvenile steppe eagle, which it displaces and suggests a wing span corresponding to that of an eastern imperial eagle. If the bird had a dark-streaked body, it would not have presented challenges for identification and would have immediately been ascribed to a juvenile eastern imperial eagle (Fergusson-Lees & Christie 2001, Svensson et al. 2014, Forsman 2016). However, I was not able to find publications, reports or expert opinions stating that juvenile eastern imperial eagles may lack the characteristic dark streaking on their bodies, which stimulated the detailed reporting of this observation. Due to the unstreaked body with creamy colour, the bird resembles a pale juvenile tawny eagle, of which there are five records from Northern Oman (Jennings 2010), most likely from its nearest known breeding grounds in Pakistan and India (Naorji 2011). However, we were not able to find photographs of these observations. Because plumage variability in the tawny eagle is higher than in any other Western Palearctic *Aquila* eagle, it is the most difficult to identify (Cramp & Simmons 1980, Clark 1992). The race of tawny eagle, occurring in South Asia *A. r. vindhiana* is smaller than the steppe eagle (Cramp & Simmons 1980, Clark 1992), while the observed eagle was larger in comparison with the juvenile steppe eagle it displaced (Fig. 1). Moreover, the observed eagle lacked the dark iris typical for juvenile tawny eagles (Svenson et al. 2009, Naorji 2009) and had barring of the remiges resembling more that of *heliaca*, than *rapax*, as the second has a more diffuse and less striking pattern (D. Forsman, in litt.). However, juvenile tawny eagles may have a pale iris (Macaulaylibrary.org), and the proportion of this trait in the population is unknown, while barring in eastern imperial eagles may vary considerably from strongly barred to no barring on the secondaries (A. Kovacs, in litt.).

Juveniles of the greater spotted and Spanish imperial eagle (*Aquila adalberti*) resemble the observed bird. The first is frequently seen in small numbers around landfills in Oman (Pröhl & Baumgart 2012, McGrady et al. 2021) during the winter and is polymorphic, with five different general morphs, including the very rare pale morph *fulvescens* (Eriksen & Porter 2017). The possibility of the bird being a greater spotted eagle was rejected primarily due to its large size, pale iris and dark-centred underwing coverts. I also considered the possibility of long-distance vagrancy by a Spanish imperial eagle but rejected the bird belonging to this species, as *adalberti* juveniles lack distinct barring on the underwing and also have a dark iris (Svenson et al. 2014).

Given that most of the literature on plumages and ageing of the eastern imperial eagle comes from birds observed in Europe and as colour morphs in raptors may show clinal variation (Martinez et al. 2016), it may be that such type of plumage is more common in parts of Asia and has remained unreported until now. In accordance with this, greater spotted eagles from Asia show much bigger colour polymorphism than birds originating from Europe (Eriksen & Porter 2017). In large eagles, individuals with rare colour morphs can be confined to specific geographic areas or distributed throughout the species range (Fontanilles et al. 2022, Dombrowski 2023). Given that only one specimen with such characteristics is described here, it cannot be concluded whether this is an extreme variant of the plumage or a new colour morph (Ellis & Dunker 2021, Ellis 2024).

Identification problems for large eagles appear when closely related species breed sympatrically, and hybridisation occurs (Lontkowski & Maciorowski 2010, Väli et al. 2010, Meyburg et al. 2020). Given the increasing number of recent records of a natural hybridisation of different *Aquila* eagles (Corso & Forsman 2008, Vali et al. 2010, Forsman 2016, Katzner et al. 2020), even though it is very unlikely, introgression of genes from other *Aquila* eagles cannot be ruled out completely, as the bird may be a backcross or later generation of imperial and tawny eagle.

In the past, tawny and steppe eagles have been considered conspecific (Fergusson-Lees & Chrisite 2001) and form a monophyletic group (Lerner & Mindell 2005). The imperial eagle is known to hybridise with the genetically more distant steppe eagle since mixed pairs of both species and backcrosses have been recorded in Kazakhstan, Russia and Turkey (Rudnick et al. 2008; Karyakin et al. 2016, Horvath et al. 2018), while the eastern imperial eagle has historically been recorded breeding in India, Pakistan and Afghanistan, but without a recent proof (Hume 1890, Ali & Ripley 1978, Fergusson-Lees & Christie 2001, Naoroji 2009, BirdLife International 2024). In November 2015, two immature eastern imperial eagles were observed building a nest in Rajasthan province, India (Mateos & Morales 2016). Towards the western end of its distribution, the tawny eagle breeds in Pakistan (Grimmett et al. 2011), where it used to be very common locally (Koning 1976) and reaches Persian Baluchistan in southeasternmost Iran, where it is resident and breeding has been suspected, but not confirmed during the last decades (Scott 2008, I. Shafaeipour, in litt.). For the case of eastern imperial and steppe eagles, in the future, increased instances of hybridisation are expected as a

side effect of the ongoing decrease of their breeding populations and lack of partners of the same species in the peripheral areas of their range (Karyakin et al. 2016). Hybridisation between steppe and tawny eagles has also been suspected in India (Donald 1952). In genetical terms, hybridisation of eastern imperial eagles with tawny eagles is more likely, compared to hybridisation with steppe eagles, given that the first two are sister species, while the steppe eagle is the sister of both of them (Helbig et al. 2005). Recent satellite tracking of two adult tawny eagles caught wintering in Rajasthan, India, showed that one of the birds migrated to Afghanistan, where transmission ceases, while the other spent the whole summer in central Kazakhstan, where it probably held a territory (Ram et al. 2022; 2024). This indicates that mixed breeding of tawny eagles with the eastern imperial eagles and steppe eagles is not impossible, as the particular observed bird stayed in areas well known for breeding of both species (Karyakin 2018a, b). More research is needed to clarify the current breeding distribution of the eastern imperial, tawny and steppe eagles in their wide contact zone in Asia.

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Abundance, taxonomic and functional diversity of raptors along aridity gradient and habitat types in Rajasthan, India

Abundancia, taxonomická a funkčná diverzita dravcov pozdĺž graditenu sucha a typov biotopov v Rádžastáne, India

Rounak CHOUDHARY , Vivek SHARMA, Pawan SINGH, Ekta SHEKHAWAT, Subroto DUTTA, Praveen MATHUR, Saba KHAN, Mayank SHARMA & Aayushi MEENA

Abstract: Birds of prey and their community structure can serve as indicators of ecosystem conditions. In this study, we analysed abundance, taxonomic and functional diversity and their variability across different levels of aridity and habitats. We recorded 43 species of raptors belonging to five families of three orders, and their taxonomic diversity was relatively uniform across the aridity gradient and habitat types. Black kite (*Milvus migrans*) and shikra (*Accipiter badius*) were the most abundant species across Rajasthan, while the long-eared owl (*Asio otus*) was the rarest. From the perspective of functional diversity, our findings suggest that the Thar Desert, being the most extreme and dry environment, supports species with specialised traits that allow them to survive harsh conditions. Results also indicate that lifestyle, beak length, tarsus length, and body mass combinations represent unique functional traits influenced by varying climatic (aridity) and ecological conditions (habitats). Understanding these functional relationships is critical for raptor conservation, particularly in arid landscapes where habitat fragmentation and food abundance fluctuations may impact species persistence.

Abstrakt: Dravé vtáky a štruktúra ich spoločenstva môžu slúžiť ako indikátory stavu ekosystému. V tejto štúdiu sme analyzovali početnosť, taxonomickú a funkčnú diverzitu dravcov a ich variabilitu pozdĺž gradientu sucha a v rôznych typov biotopov. Zaznamenali sme 43 druhov dravých vtákov patriacich do piatich čeľadí troch radov. Ich taxonomická diverzita bola relatívne uniformná, tak v rámci gradientu sucha ako aj typov biotopov. Haja tmavá (*Milvus migrans*) a jastrab šikra (*Accipiter badius*) boli najpočetnejšími druhmi v celom Rádžastáne, zatiaľ čo myšiarka ušatá (*Asio otus*) bola najvzácnejšia. Z hľadiska funkčnej diverzity naše zistenia naznačujú, že púšť Thar, ktorá je najextrémnejším a najsuchším prostredím, podporuje druhy so špecializovanými vlastnosťami, ktoré im umožňujú prežiť v drsných podmienkach. Výsledky tiež naznačujú, že kombinácie životného štýlu, dĺžky zobáka, dĺžky tarsusu a telesnej hmotnosti predstavujú jedinečné funkčné znaky ovplyvnené rôznymi klimatickými (aridita) a ekologickými podmienkami (biotop). Porozumenie týchto funkčných vzťahov je kľúčové pre ochranu dravcov, najmä v suchých územiach, kde fragmentácia biotopov a kolísanie množstva potravy môžu ovplyvniť prezistenciu druhov.

Key words: birds of prey, functional traits, predators, owls, scavengers, conservation

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Introduction

The term 'raptor' refers to avian species from the Accipitriformes, Cathartiformes, Falconiformes, and Strigiformes orders (McClure et al. 2019), and they are the top avian predators in most terrestrial environments around the World (McClure et al. 2018). Raptors are renowned for their hunting abilities, which include using a sharp cutting edge with a hooked bill, strong and powerful legs for grasping their prey, acute eyesight, speed, and flight strength (Bildstein 2017). Raptors are further classed as predators and scavengers based on their role in the ecosystem (Donazar 2016). Predators play an essential role in ecosystem structure and function by controlling prey populations. In contrast, scavengers ensure the flow of nutrients in the food chain and prevent disease spread by feeding on dead organisms. Raptors are more vulnerable to anthropogenic pressures and extinction than other bird species (O'Bryan et al. 2022) as they occur at low population densities due to occupying high trophic levels and have slow life histories (Owens and Bennett 2000; Sergio et al. 2008). Their threats include, e.g., climate change (Iknayan and Beissinger 2018), electrocution (Lehman 2001; Kouba et al. 2021), habitat alterations (Bildstein 2006) and intentional or unintentional poisoning (Oaks et al. 2004; Brochet et al. 2017).

Aridity plays a fundamental role in shaping landscape habitat characteristics, influencing vegetation structure, water availability, soil composition, and species distribution. At broader spatial scales, bird communities in arid-semiarid environments are thought to be generally independent of habitat structure, with climatic variables having a greater influence (Rotenberry 1978; Naranjo & Raitt 1993; Kaboli et al. 2006). Aridity and land cover heterogeneity may impact bird food resources, affecting species diversity and richness in a particular area (Lorenzón et al. 2016). Communities in these landscapes ought to consist of species with survival abilities.

Along the aridity gradient, environmental filtering is strong and favours species with specific survival traits for drought and heat tolerance (Díaz et al. 1998; Joseph et al. 2014). As a result, functional diversity is often reduced because only a limited set of functional traits enables survival under such conditions. Although direct studies on aridity are limited, research indicates that aridity is generally associated with lower species diversity, especially in tropical regions (Hawkins et al. 2003; Oliveira et al. 2022). Furthermore, studies suggest that bird functional diversity can decline more rapidly than species richness, indicating that functionally distinct species are often lost first (Flynn et al. 2009; Luck et al. 2013). Although these

findings primarily come from studies on land-use change, they imply that similar patterns could also occur along aridity gradients.

The diversity of raptors is linked to several environmental factors (Voskamp et al. 2017), with habitat type and seasonality playing key roles in shaping community dynamics (Morrison et al. 2006). Habitat structure and heterogeneity significantly influence the species richness and abundance of raptor communities by providing varied foraging opportunities, nesting sites, and perching structures (White 1974; Thiollay 2006). Different habitat types support distinct assemblages of raptors depending on their hunting strategies, dietary preferences, and nesting requirements (Guisan et al. 2017; Morrison 2012). These differences affect taxonomic diversity and shape raptors' functional diversity by promoting species' coexistence with different ecological roles and adaptations. Therefore, understanding how raptor communities respond to habitat characteristics is essential for effective habitat management and conservation planning (Thiollay 2006; Morrison 2012).

So, evaluating taxonomic and functional diversity in relation to the aridity gradient and habitat should provide insights into the mechanisms by which species losses or additions that have specific functional features affect ecosystem functioning (Kremen 2005). Therefore, functional diversity is defined as a component of biodiversity that describes the degree of functional differences between species (e.g., how organisms use resources) and measures the distribution and range of the organisms' effects on the ecosystem. It considers redundancy and complementarity among co-occurring species, which determine the stability and efficiency of ecological processes (Díaz & Cabido 2001; Petchey & Gaston 2006). On the other hand, activities such as agriculture have been shown to help some raptor species by creating new niches with increased prey availability and visibility for hunting across larger areas (Grande et al. 2018).

For the conservation and management of raptors, it is crucial to understand their distribution in environmental space, which essentially requires baseline information on their occurrence. In this study, we assessed and described raptors' abundance and taxonomic and functional diversity observed over two years along an aridity gradient in open, closed and mosaic habitats.

Materials and Methods

Study area

Our study was conducted in Rajasthan, India's largest state, within the arid and semi-arid biogeographic zones (Fig. 1A).

Limited water resources, scarce arable land, high evapotranspiration, sparse vegetation, rodent infestations, and the lack of perennial rivers mark Rajasthan's arid environment. The prevailing climate types include dry temperate, warm semi-dry temperate, and temperate sub-humid, with summer precipitation in some areas. The region's natural vegetation consists of grasslands and desert scrublands, while agriculture and rangelands dominate the land cover (Fig. 1B). Large portions of the Thar Desert have been altered by human activity, with agriculture exerting significant pressure on native plant communities. Northern tropical thorn forests (Champion & Seth 1968) characterise the rolling arid landscape, featuring particularly the following species: *Acacia capparis*, *Acacia catechu*, *Acacia senegal*, *Anogeissus pendula*, *Azadirachta indica*, *Butea monosperma*, *Prosopis cineraria* and invasive *Prosopis juliflora*. The study area spans 0.342 million square kilometres, located between 23.4° and 29.7° N latitude and 69.3° and 78.3° E longitude. The arid and semi-arid zones harbour more than 450 bird species (Sharma et al. 2013). The Aravalli Hills separate these zones, acting as a natural climatic and ecological barrier that influences vegetation and wildlife distribution. These zones form a distinct aridity gradient, shaping the region's environment and fauna. Rajasthan's arid region includes the Thar Desert, characterised by low and variable rainfall (100–400 mm per year), high temperatures, and sandy terrain. In comparison, the semi-arid region of Rajasthan receives significantly more rainfall (400–800 mm) and features a more diverse mosaic of grasslands, scrublands, dry deciduous woods, and agricultural fields. The aridity gradient in Rajasthan spans about 800 km (Fig. 1C).

Data Collection

Raptors' diversity was recorded from November 2022 to January 2025. All 36 sampling locations were distributed across Rajasthan's aridity gradient to ensure representation of diverse habitats. All study zones were surveyed at least five times during different seasons (summer, monsoon and winter). Transect surveys were conducted during peak raptor activity periods: mornings from 07:00–11:00 and evenings from 16:00 till sunset (Bunn et al. 1995; Vergara 2010; Tiwari et al. 2023). Multiple observation points and transects of varying lengths were established within the sampling locations. Transect placement followed a semi-random approach, considering accessibility in hilly and forested regions. Road transects spanned 3–20 km and were conducted in a vehicle at a maximum speed of ~50 km/h. Line

transects, ranging from 0.1 to 3 km, were walked on foot. Observation points were strategically placed to

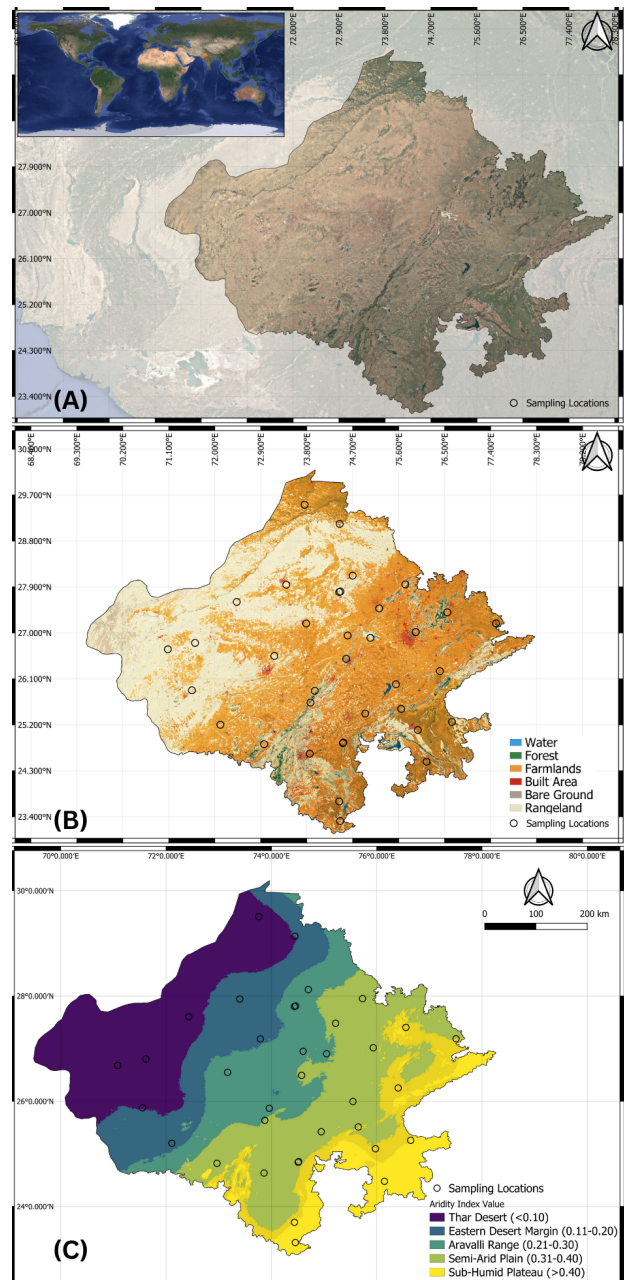


Fig. 1. Map of study area highlighting Rajasthan on a global map (A), habitat types with sampling locations (B), and Aridity Index Value across the study area (C); defined as the ratio of precipitation to potential evapotranspiration).

Obř. 1. Mapa ťtudovanej oblasti s vyznaĹením Rádřžastánu na globálnej mape (A), typy biotopov v spolu so vzorkovacími lokalitami (B) a Indexu suchosti v ťtudovanej oblasti (C; definovaná ako pomer zřážok k potenciálnej evapotranspirácii).

count flying raptors within a 1–2 km radius and to monitor vultures feeding on carcasses. Occasional sightings near designated sampling locations were also included in the analysis. Raptors were identified in the field based on morphological characteristics and behaviour (Naoroji 2006). Unidentified individuals were photo-documented for later confirmation.

During surveys, each raptor sighting was classified into two levels: 1. habitat categories: Open habitats (represented grasslands, wetlands, rangelands, etc.), Closed habitats (closed-canopy woodlands, forests, etc.) and Mosaic habitats (heterogeneous habitats dominated by farmlands) (Fig. 1B) and 2. five aridity zones: Thar Desert (<0.10 Aridity Index Value – AIV, see below for details), Eastern Desert Margin (0.11–0.20 AIV), Aravalli Hills (0.21–0.31 AIV), Semi-Arid Plain (0.31–0.40 AIV) and Sub-Humid Plateau (>0.40 AIV) (Fig. 1C). Aridity zones were defined by Aridity Index Value (AIV) as the ratio of precipitation to potential evapotranspiration. For classification and visualisation of aridity index across Rajasthan, we used high-resolution (30 arc-seconds) global raster climate data (Zomer & Trabucco 2019).

We used species richness as an indicator of taxonomic diversity. For selected functional traits, we used the AVONET dataset (Tobias et al. 2022), which contains bird species’ morphological and ecological data and the EltonTraits 1.0 dataset for Raptor activity attributes (Wilman et al. 2014) (Table 1).

For alpha functional diversity analysis we used multiple indices including Functional Dispersion (FDis) that measures trait dispersion within the community (Laliberté & Legendre 2010), Functional Richness (FRic) reflects the volume of functional space occupied by species (Cornwell et al. 2006; Villéger et al. 2008), representing the breadth of trait diversity, Functional Divergence (FDiv) assesses how species are distributed relative to the center of the functional space (Villéger et al. 2008), Functional Evenness (FEve) describes how evenly species are distributed in trait space (Villéger et al. 2008), Functional Specialisation (FSpe) indicates the degree to which species are functionally specialised (Bellwood et al. 2006, Mouillot et al. 2013), Functional Mean Pairwise Distance (FMPD) calculates the average functional distance between all possible species pairs in the community (Weiher et al. 1998), Functional Mean Nearest Neighbour Distance (FNND) measures how functionally unique each species is relative to its closest neighbour (Weiher et al. 1998) and Functional Originality (FOri) that quantifies the uniqueness of species traits within a community (Mouillot et al. 2013).

We used the Jaccard Dissimilarity index for beta

Tab. 1. Functional traits of raptors used in the analysis of functional diversity.

Tab. 1. Funkčné znaky dravcov použitých v analýze funkčnej diverzity.

Trait	Range	Description
Beak Length (mm)	17.9–87.8	Beak morphology reflects feeding specialisation.
Beak Depth (mm)	10–39.8	
Tarsus Length (mm)	25.6–134.2	The tarsus length (lower leg segment) influences perching, prey capture, and locomotion.
Hand Wing Index (HWI)	27.4–57.8	HWI reflects wing shape and flight efficiency.
Tail Length (mm)	74.2–371	Tail length affects flight agility and manoeuvrability.
Mass (g)	112–9798	Body mass influences metabolic rate, energy demands, and predation risk.
Habitat	Forest-Grassland- Human Modified-Rock- Shrubland-Wetland- Woodland	Habitat preference defines niche specialisation.
Niche	Aquatic Predator- Invertivore-Omnivore- Scavenger-Vertivore	The trophic niche determines a raptor’s role in ecosystem functioning.
Lifestyle	Aerial-Generalist- Insessorial-Terrestrial	Lifestyle categorise hunting strategies.
Activity Period	Diurnal-Nocturnal	Diurnal raptors rely on daylight for hunting, while nocturnal species have specialised adaptations like silent flight and enhanced night vision, affecting their ecological role and competition.

functional diversity analysis, which measures the total functional dissimilarity between two communities (Chao et al. 2019). To gain deeper insight into the source of functional dissimilarity, the total Jaccard dissimilarity can be partitioned into two components: Jaccard Turnover and Jaccard Nestedness (Baselga 2012). The turnover quantifies the extent to which functional dissimilarity arises from replacing or substituting functional traits between communities. A high turnover value indicates that functional differences are primarily due to different species performing different ecological roles in the two communities. In contrast, nestedness measures the part of functional dissimilarity that results from differences in trait richness. A high nestedness value suggests that the observed dissimilarity is not due to species replacement but rather the loss or absence of specific functional traits in one of the communities. The alpha and beta functional diversity analysis was performed using the “mFD” package (Magneville et al. 2022).

Data analysis

Principal Coordinates Analysis was performed following the approach of Gower (1966), using the vegan package (Oksanen et al. 2025) to explore patterns of functional diversity in raptor communities along the aridity gradient. To statistically test the influence of variables on trait composition, we conducted Permutational Multivariate Analysis of Variance using the vegan package with 999 permutations, based on the Euclidean distance matrix. The analysis was based on functional traits of the species. We used species abundance and raptor-traits data to measure different functional diversity indices. The taxonomic composition was assessed using Euclidean distance-based clustering of species traits using the stats package in R software (R Core Team 2024). Species diversity was evaluated as species richness using rarefaction and extrapolation curves generated with the iNEXT package (Hsieh et al. 2024). We used Spearman’s rank correlation to assess the strength and direction of monotonic relationships between aridity and each functional diversity index. All analyses were performed using R software (R Core Team 2024).

Results

Rank-abundance of raptors

A total of 1,182 individuals were recorded during the study, specifically 156 in the landscape of the Thar Desert (13.2%), 213 in the Eastern Desert Margin (18%), 244 in the Aravalli Hills (20.6%), 330 in the Semi-arid Plains (27.9%), and 239 in the Sub-humid Plateau (20.2%).

In the context of habitat, in open habitats 485 (41%), in closed habitats 413 (34.9%), and in mosaic habitats (having a mix of open and closed habitats along with farmlands) 284 (24%) individuals were recorded. The most abundant species were black kite (*Milvus migrans*; 12.9%), shikra (*Accipiter badius*; 9.3%), Egyptian vulture (*Neophron percnopterus*; 8.9%), spotted owl (*Athene brama*; 8.7%) and Eurasian griffon vulture (*Gyps fulvus*; 5.8%). In comparison, the short-eared owl (*Asio flammeus*; 0.3%), black eagle (*Ictinaetus malaiensis*; 0.2%) and long-eared owl (*Asio otus*; 0.1%) were the rarest species (Fig. 2).

Species richness

A total of 43 raptor species were recorded during the study in Rajasthan. No marked differences in species richness were observed between habitats. Closed habitats like forests and woodlands exhibit the highest species richness (40 species), followed closely by open habitats like rangelands (39 species), while mosaic habitats like farmlands support fewer species (37 species) (Appendix 1). Species richness was highest in the Semi-arid Plains (41 species), while the other zones exhibited comparable values (36–38 species), suggesting relatively uniform raptor diversity across the aridity gradient (Appendix 2).

Functional Diversity

Principal Coordinates Analysis (PCA) shows the multidimensional trait space of 43 raptor species recorded in Rajasthan based on morphological and ecological traits (Fig. 3). The first two Principal Coordinates Analysis axes

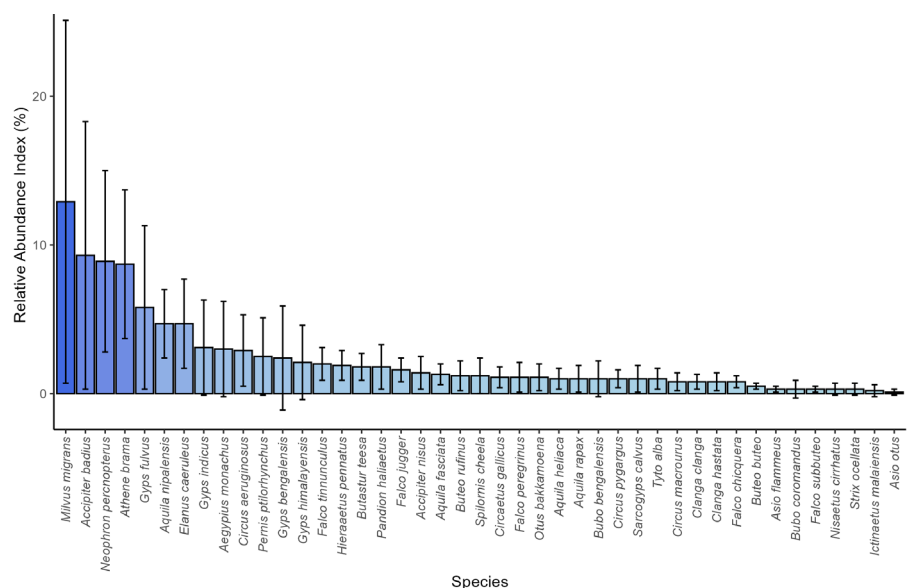


Fig. 2. Relative abundance of raptors (% \pm SD) of species recorded in Rajasthan.

Obř. 2. Relatívna abundancia dravcov (% \pm SD) druhov zaznamenaných v Rádžastáne.

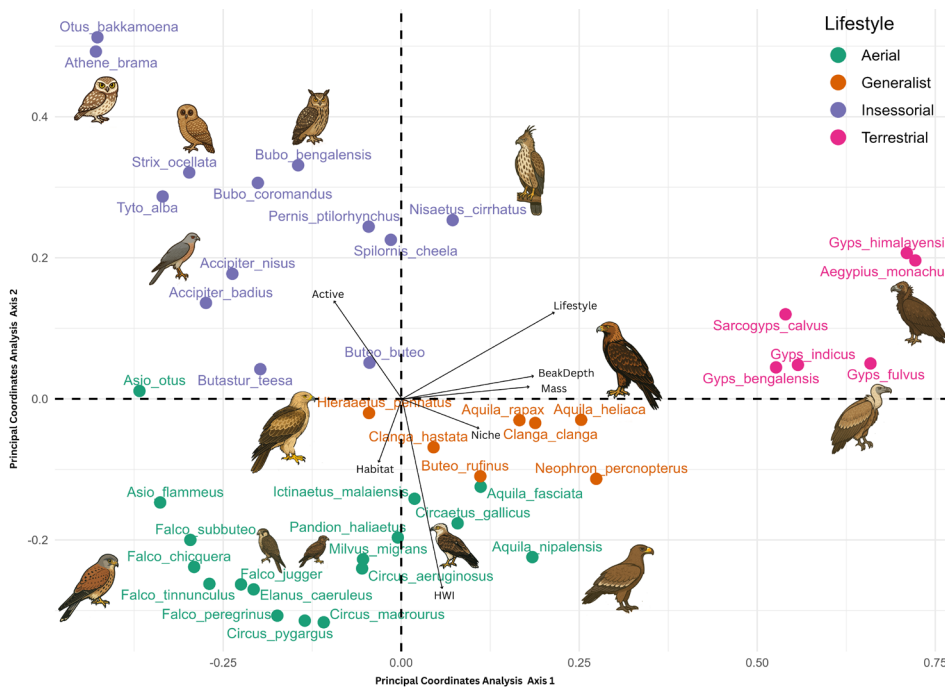


Fig. 3. PCA analyses of the multidimensional traitspace of raptors (n = 43 species) in Rajasthan.

Obr. 3. PCA analýza viacrozmerného priestoru znakov dravcov (n = 43 druhov) v Rádžastáne.

explained 25.72% and 15.31% of the total trait variation, respectively. Permutational Multivariate Analysis of Variance results showed that habitat ($R^2=0.646$, $F=23.77$, $p=0.023$) and lifestyle ($R^2=0.518$, $F=10.24$, $p=0.001$) explained the highest variation in the raptor trait space among ecological factors. Among morphological traits, beak length ($R^2=0.453$, $F=34.08$, $p=0.001$), tarsus length ($R^2=0.428$, $F=30.80$, $p=0.001$), and body mass ($R^2=0.424$, $F=30.25$, $p=0.001$) were the strongest predictors of trait differentiation. The analysis showed distinct functional clustering, with large-bodied, terrestrial scavengers such as vultures occupying the positive end of Axis 1, while smaller, aerial foragers such as falcons are positioned toward the negative axis (Fig. 3).

Functional diversity metrics showed distinct ecological patterns across the aridity gradient (Table 2). The Thar Desert have high functional dispersion and divergence ($FDis=0.702$; $FDiv=0.829$), suggesting strong ecological differentiation and specialisation among species, but low functional evenness and originality ($FEve=0.634$; $FOri=0.337$), indicating trait clustering and limited uniqueness. In contrast, the Eastern Desert Margin and Semi-arid Plains showed the highest functional richness ($FRic=0.919$ and 0.923), indicating a broad range of ecological roles, along with relatively

high originality ($FOri=0.390$ and 0.373), respectively, suggesting a mix of specialists and unique species. The Aravalli Range displayed high evenness ($FEve=0.729$) but lower dispersion ($FDis=0.585$) and specialisation ($FSpe=0.486$), pointing to functional redundancy and dominance of generalist traits. The Sub-humid Plateau had the lowest functional richness ($FRic=0.745$) and generally moderate values across other metrics, implying reduced ecological differentiation and a more uniform trait structure. Overall, arid regions tended to support more specialised and divergent raptor communities, while mesic zones hosted more functionally redundant and generalist assemblages. Raptor communities differed across habitats in their ecological roles. Closed habitats had the highest functional dispersion ($FDis=0.663$), indicating a wider range of traits due to complex vegetation and diverse prey, while mosaic habitats had lower dispersion ($FDis=0.593$), suggesting functional redundancy. Functional divergence remained high in closed ($FDiv=0.812$) and farmlands mosaic ($FDiv=0.820$) habitats, showing distinct trait differences among species (Table 2).

We have not found a significant correlation between aridity and functional evenness (Spearman's rank correlation: $\rho=0.7$, $p=0.2$), and functional mean pairwise distance (Spearman's rank correlation: $\rho=-0.6$, $p=0.3$).

Tab. 2. Functional diversity metrics across different landscapes (classified by aridity index).
Tab. 2. Ukazovatele funkčnej diverzity klasifikované podľa indexu suchosti a typu biotopu.

Landscape	Aridity Index Value	Species Richness	Functional Dispersion	Functional	Functional	Functional Evenness	Functional Richness	Functional Divergence	Functional Originality	Functional Specialisation
				Mean Pairwise Distance	Mean Nearest Neighbour Distance					
Thar Desert	<0.10	36	0.702	0.724	0.34	0.634	0.81	0.829	0.337	0.623
Eastern Desert Margin	0.11-0.20	38	0.622	0.687	0.396	0.642	0.919	0.792	0.39	0.567
Aravalli Hills	0.21-0.30	36	0.585	0.613	0.382	0.729	0.766	0.804	0.363	0.486
Semi-Arid Plains	0.31-0.40	41	0.583	0.638	0.379	0.651	0.923	0.802	0.379	0.491
Sub-Humid Plateau	>0.40	37	0.638	0.657	0.377	0.659	0.745	0.814	0.366	0.519
Habitat Type										
Open		39	0.637	0.661	0.382	0.616	0.919	0.769	0.37	0.53
Closed		40	0.663	0.672	0.337	0.667	0.806	0.812	0.337	0.542
Mosaic		37	0.593	0.638	0.423	0.638	0.706	0.82	0.416	0.499

Dissimilarity, Turnover and Nestedness

The Jaccard dissimilarity values (Table 3) showed that the Thar Desert had the most distinct raptor species composition, with high dissimilarity from the Sub-humid Plateau (0.4) and Aravalli Range (0.394), but was most similar to the adjacent Eastern Desert Margin (0.119). The Eastern Desert Margin showed moderate dissimilarity with the Aravalli Range (0.294) and the Semi-arid Plains (0.150), reflecting its intermediate position. Jaccard turnover was highest between the Thar Desert and the Aravalli Range (0.366) and the Sub-humid Plateau (0.357), indicating major species replacement along the aridity gradient. Nestedness was highest between the Semi-arid Plains and Sub-humid Plateau (0.193), suggesting partial species retention. In contrast, nestedness between the Eastern Desert Margin and Semi-arid Plains was negligible (0.003), indicating compositional differences were driven by turnover rather than species loss.

Discussion

The recorded birds of prey abundances offer important context for interpreting their distribution patterns and functional structure across the Rajasthan landscape. The high abundance of generalist species like black kites and shikras is consistent with patterns observed in a previous study of the arid landscape of Rajasthan (Tiwari et al. 2021). We recorded the highest abundance in open habitats; such habitats can offer raptors enhanced foraging efficiency due to greater visibility (Sergio et al. 2005; Eduardo et al. 2007). In contrast, the least abundance of raptors was found in mosaic habitats. These often represent transitional or fragmented zones, where human disturbance, edge effects, or resource unpredictability may reduce habitat quality for certain raptors (Butet et al. 2022).

Previous research has documented the Indian sub-continent as home to a diverse raptor assemblage (Baker

Tab. 3. Pairwise comparisons of the raptors across the landscapes of Rajasthan.

Tab. 3. Párové porovnanie dravcov v krajine Rádžasthánu.

Index	Jaccard Dissimilarity				Jaccard Turnover				Jaccard Nestedness			
	Thar Desert	Eastern Desert Margin	Aravalli Hills	Semi-Arid Plain	Thar Desert	Eastern Desert Margin	Aravalli Hills	Semi-Arid Plain	Thar Desert	Eastern Desert Margin	Aravalli Hills	Semi-Arid Plain
Eastern Desert Margin	0.119				0				0.119			
Aravalli Hills	0.394	0.294			0.366	0.165			0.028	0.129		
Semi-Arid Plain	0.239	0.15	0.266		0.14	0.147	0.125		0.099	0.003	0.141	
Sub-Humid Plateau	0.4	0.315	0.128	0.193	0.357	0.168	0.104	0	0.043	0.147	0.024	0.193

1928; Ali & Ripley 1978; 1983; 1987; Naoroji 2006; Naoroji & Sangha 2013). Today, more than 112 raptor species are found in India (Praveen & Jaypal 2024). We recorded 43 raptor species across different aridity zones of Rajasthan. Previous studies documented 35 species in Rajasthan (Tiwari et al. 2023) and 30 species specifically in the Jaisalmer District of the Thar Desert (Bora et al. 2023). Additionally, recent records from citizen science platforms have reported the presence of over 60 raptor species in Rajasthan (eBird 2025). Among recorded raptors, white-rumped vulture (*Gyps bengalensis*), Indian vulture (*Gyps indicus*), and red-headed vulture (*Sarcogyps calvus*) are classified as Critically Endangered. Others, like the steppe eagle (*Aquila nipalensis*) and Egyptian vulture, are classified as Endangered, four species are listed as Vulnerable, and five as Near Threatened according to the International Union for Conservation of Nature Red List (IUCN 2025).

No marked differences in raptor species richness were found across the study area's aridity zones and habitats. Carrete et al. (2009) noted that raptor species richness has been shown to decline with increasing habitat modification resulting from anthropogenic activities. While habitat degradation generally negatively impacts raptors, certain species may benefit from heterogeneous landscapes and low-intensity agriculture, as these conditions create new ecological niches with increased prey availability and improved hunting visibility (Fleming & Bateman 2018). However, numerous threats contribute to raptor population declines, including habitat destruction (McClure et al. 2018), poisoning (Green et al. 2004; Green et al. 2022; Ogada et al. 2012), electrocution (Lehman et al. 2007; Kouba et al. 2021), free-ranging dogs (Gompper et al. 2014), destruction of nesting sites and the broader effects of climate change. Particularly in Rajasthan, the expansion of renewable energy infrastructure, including wind and solar farms in the Thar Desert, has introduced high-tension power lines, significantly impacting raptor populations (Uddin et al. 2021). Further, free-ranging dogs are increasingly recognised as a major threat to vultures and large raptors in the arid landscape of Rajasthan.

The functional diversity of raptors in Rajasthan suggests ecological groupings based on morphological traits (beak length, tarsus length, and body mass), habitat, and lifestyle adaptations. These groupings highlight how different species partition ecological roles, showcasing variations in hunting strategies, flight morphology, and habitat preferences. Raptors in the region thus can be broadly categorised into four functional groups:

scavengers, aerial hunters, perch-and-ambush predators, and generalists. Scavenging vultures like white-rumped vulture, Eurasian griffon vulture, Himalayan vulture (*Gyps himalayensis*), Indian vulture, cinereous vulture (*Aegypius monachus*), and red-headed vulture are distinctly separated from active hunters due to their obligate dependence on carrion and soaring flight adaptations (Selva et al. 2019). Vultures exhibit specialised adaptations, including longer wingspans for efficient soaring, reduced tarsus length, and robust beaks for tearing carrion, which reinforce their functional separation from other raptors (Campbell 2015; Negro and Galvan 2018).

The members of the aerial hunting guild, which comprises falcons like peregrine falcon (*Falco peregrinus*), common kestrel (*Falco tinnunculus*), red-necked falcon (*Falco chicquera*), *Accipiter* species like Eurasian sparrowhawk (*Accipiter nisus*), shikra and kites like black kite, black-winged kite (*Elanus caeruleus*), are adapted for high-speed pursuits, possessing shorter wingspans, high aspect ratio wings, and sharp talons to capture agile prey (Spaar 1997; Dunne and Karlson 2017). Harriers like pallid harrier (*Circus macrourus*), western marsh harrier (*Circus aeruginosus*) demonstrate functional similarities to other aerial hunters but differ in their preference for open grasslands and wetlands, using low-altitude gliding to detect prey. Eagles like the steppe eagle, tawny eagle (*Aquila rapax*) and larger *Buteo* species adopt a mixed hunting strategy, alternating between soaring flight and perch hunting, displaying intermediate wing morphology suited for both gliding and short bursts of speed.

Particular species exhibit unique ecological adaptations at the extremes of the functional space. The Egyptian vulture's opportunistic feeding behaviour and ability to exploit a wide range of food resources, including small vertebrates and human refuse, differentiate it from obligate scavengers (Di Vittorio et al. 2017). In contrast, the piscivorous diet of osprey (*Pandion haliaetus*) and its specialised hunting technique, characterised by reversible outer toes and spiny foot pads, place it outside terrestrial raptors' primary clustering (Clancy 2005). This functional trait differentiation facilitates species' resource partitioning and hierarchical feeding interactions (Byrne et al. 2019). Five of the ten monitored traits, i.e., beak depth, hand-wing index, tail length, niche and activity period, had no significant influence on functional trait differentiation. Key traits, i.e., beak length, tarsus length, and body mass, exhibit co-variation, reflecting their role in shaping predatory efficiency. Raptors with longer tarsi and shorter wings are adapted for manoeuvrable hunting in cluttered habitats

(Ward et al. 2002), while those with larger body mass and longer wings specialise in soaring flight and long-distance travel (Duriez et al 2014). The alignment of these traits reinforces the structured functional diversity observed among Rajasthan's raptor assemblage. The observed patterns of functional diversity emphasise the ecological specialisation and niche differentiation among raptors in Rajasthan. While some species exhibit functional redundancy, ensuring ecosystem stability, others occupy highly specialised roles, making them vulnerable to environmental changes.

The Jaccard dissimilarity across different arid regions highlighted how raptor species composition changes along the aridity gradient. Species composition in the Thar Desert, the most arid area in this study, was quite distinct from that of more humid regions. The Eastern Desert Margin acted as a transitional zone, similar to the Thar Desert. The Aravalli Range and the Semi-arid plains allowed species from both arid and semi-arid regions to coexist. However, its higher dissimilarity with the Sub-humid Plateau indicated that aridity changes led to species composition alterations. The Jaccard turnover values further support these patterns, with the highest species replacement occurring between the Thar Desert and Aravalli Range and Sub-humid Plateau, indicating an almost complete shift in species composition along with the climate transition from extreme arid to mesic conditions.

The Jaccard nestedness reveals patterns of species loss along the aridity gradient. The highest nestedness occurs between the Semi-arid Plains and Sub-humid Plateau, indicating that many species in the Semi-arid Plains persist in the Sub-humid Plateau, though some disappear as conditions become wetter. In contrast, nestedness is extremely low between the Eastern Desert Margin and the Semi-arid Plains. This implies that species differences arise mainly from species turnover rather than a stepwise loss, reinforcing the Eastern Desert Margin's role as a species-rich ecological corridor. This area is special since the Eastern Desert Margin has such low nestedness. It's not just a transition zone but a mixing ground where many species from both arid and semi-arid areas coexist. Additionally, transitional zones, such as the Eastern Desert Margin and Semi-Arid Plains, are crucial in maintaining species diversity by mitigating biodiversity loss and facilitating gradual species shifts (Smith et al. 2001). Semi-arid and sub-humid zones require conservation strategies to prevent species loss, as nestedness patterns indicate a gradual decline in biodiversity rather than species replacement. Closed habitats supported the most functionally diverse

raptor communities, with species occupying more specialised roles and maintaining an even functional distribution. This may reflect the ecological complexity of closed habitats such as forests and woodlands, which offer various environments for species ranging from canopy-dwelling raptors to understory hunters (Hussin & Francis 2001). Open habitats like rangelands exhibited the highest functional richness, as they accommodate various ecological strategies, including scavengers and large aerial foragers (O'reagain & Schwartz 1995). Habitat heterogeneity is essential in sustaining functional diversity (Alsterberg et al. 2017), highlighting the value of conserving a mix of open and closed habitats. Fragmentation of forested areas could reduce functional specialisation, impacting species that depend on specific structural features or prey types (Dos Anjos et al. 2019). Similarly, the degradation of open habitats may affect species with unique functional traits, such as scavengers and wide-ranging hunters (Pringle et al. 2019). Protecting diverse habitat types can therefore support the long-term ecological balance of raptor communities and help maintain the variety of roles they play within ecosystems. Tailored conservation approaches may be beneficial for arid areas to address their unique species compositions. The observed functional diversity of raptors has critical conservation implications. Raptors with high functional redundancy may help buffer against species loss, as other functionally similar species could partially compensate for declines. However, functionally unique species, particularly specialist scavengers and piscivores, are more vulnerable to environmental changes and habitat degradation.

The observed clustering of raptor species suggested that conservation efforts should prioritise preserving functional diversity rather than focusing solely on species richness (Cadotte et al. 2011). Protecting key habitats that support different raptor guilds, such as open plains for falcons, wetlands for harriers and ospreys, and forested patches for *Accipiter* species, is essential for maintaining ecosystem stability (Mundy 1995; Donázar et al. 2016).

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Appendix 1. Abundance and relative abundance of raptors in three different habitat categories in Rajasthan.

Príloha 1. Abundancia a relativná abundancia dravcov v troch rôznych typoch biotopov v Rádžastáne.

Species	Open		Closed		Mosaic		Total	
	n	%	n	%	n	%	n	%
<i>Accipiter badius</i>	15	3.1	65	15.7	30	10.6	110	9.3
<i>Accipiter nisus</i>	8	1.7	5	1.2	3	1.1	16	1.4
<i>Aegypius monachus</i>	32	6.6	3	0.7	1	0.4	36	3.0
<i>Aquila fasciata</i>	3	0.6	11	2.7	1	0.4	15	1.3
<i>Aquila heliaca</i>	9	1.9	2	0.5	1	0.4	12	1.0
<i>Aquila nipalensis</i>	30	6.2	20	4.8	5	1.8	55	4.7
<i>Aquila rapax</i>	8	1.7	2	0.5	2	0.7	12	1.0
<i>Asio flammeus</i>	2	0.4	1	0.2	0	0	3	0.3
<i>Asio otus</i>	1	0.2	0	0	0	0	1	0.1
<i>Athene brama</i>	20	4.1	70	17	13	4.6	103	8.7
<i>Bubo bengalensis</i>	8	1.7	3	0.7	1	0.4	12	1.0
<i>Bubo coromandus</i>	0	0	4	1	0	0	4	0.3
<i>Butastur teesa</i>	7	1.4	13	3.2	1	0.4	21	1.8
<i>Buteo buteo</i>	2	0.4	3	0.7	1	0.4	6	0.5
<i>Buteo rufinus</i>	10	2.1	2	0.5	2	0.7	14	1.2
<i>Circaetus gallicus</i>	2	0.4	10	2.4	1	0.4	13	1.1
<i>Circus aeruginosus</i>	22	4.5	4	1	8	2.8	34	2.9
<i>Circus macrourus</i>	9	1.9	0	0	1	0.4	10	0.8
<i>Circus pygargus</i>	8	1.7	1	0.2	3	1.1	12	1.0
<i>Clanga clanga</i>	8	1.7	1	0.2	1	0.4	10	0.8
<i>Clanga hastata</i>	2	0.4	5	1.2	2	0.7	9	0.8
<i>Elanus caeruleus</i>	40	8.3	5	1.2	10	3.5	55	4.7
<i>Falco chicquera</i>	6	1.2	2	0.5	1	0.4	9	0.8
<i>Falco jugger</i>	15	3.1	1	0.2	3	1.1	19	1.6
<i>Falco peregrinus</i>	3	0.6	8	1.9	2	0.7	13	1.1
<i>Falco subbuteo</i>	3	0.6	0	0	0	0	3	0.3
<i>Falco tinnunculus</i>	14	2.9	2	0.5	8	2.8	24	2.0
<i>Gyps bengalensis</i>	5	1	20	4.8	3	1.1	28	2.4
<i>Gyps fulvus</i>	38	7.8	12	2.9	19	6.7	69	5.8
<i>Gyps himalayensis</i>	15	3.1	3	0.7	7	2.5	25	2.1
<i>Gyps indicus</i>	7	1.4	21	5.1	9	3.2	37	3.1
<i>Hieraaetus pennatus</i>	6	1.2	12	2.9	4	1.4	22	1.9
<i>Ictinaetus malaiensis</i>	0	0	2	0.5	0	0	2	0.2
<i>Milvus migrans</i>	55	11.3	23	5.6	75	26.4	153	12.9
<i>Neophron percnopterus</i>	49	10.1	12	2.9	44	15.5	105	8.9
<i>Nisaetus cirrhatus</i>	0	0	3	0.7	1	0.4	4	0.3
<i>Otus bakkamoena</i>	1	0.2	9	2.2	3	1.1	13	1.1
<i>Pandion haliaetus</i>	8	1.7	6	1.5	7	2.5	21	1.8
<i>Pernis ptilorhynchus</i>	4	0.8	21	5.1	5	1.8	30	2.5
<i>Sarcogyps calvus</i>	4	0.8	7	1.7	1	0.4	12	1.0
<i>Spilornis cheela</i>	1	0.2	11	2.7	2	0.7	14	1.2
<i>Strix ocellata</i>	0	0	4	1	0	0	4	0.3
<i>Tyto alba</i>	5	1	4	1	3	1.1	12	1.0
Total	485	100	413	100	284	100	1182	100
Total Species	39		40		37		43	

Appendix 2. Abundance and relative abundance of raptors in five different aridity zones in Rajasthan.

Príloha 2. Abundancia a relatívna abundancia dravcov v piatich rôznych zónach sucha v Rádžastáne.

Species	Thar Desert		Eastern Desert Margin		Aravalli Hills		Semi-Arid Plains		Sub-Humid Plateau		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
<i>Accipiter badius</i>	4	2.6	7	3.3	18	7.4	54	16.4	27	11.3	110	9.3
<i>Accipiter nisus</i>	1	0.6	2	0.9	7	2.9	4	1.2	2	0.8	16	1.4
<i>Aegypius monachus</i>	18	11.5	11	5.2	0	0	3	0.9	4	1.7	36	3.1
<i>Aquila fasciata</i>	1	0.6	3	1.4	5	2.1	4	1.2	2	0.8	15	1.3
<i>Aquila heliaca</i>	4	2.6	4	1.9	2	0.8	1	0.3	1	0.4	12	1
<i>Aquila nipalensis</i>	12	7.7	15	7	16	6.6	9	2.7	3	1.3	55	4.7
<i>Aquila rapax</i>	5	3.2	4	1.9	2	0.8	1	0.3	0	0	12	1
<i>Asio flammeus</i>	1	0.6	1	0.5	1	0.4	0	0	0	0	3	0.3
<i>Asio otus</i>	0	0	1	0.5	0	0	0	0	0	0	1	0.1
<i>Athene brama</i>	12	7.7	9	4.2	25	10.3	37	11.2	20	8.4	103	8.7
<i>Bubo bengalensis</i>	0	0	2	0.9	7	2.9	2	0.6	1	0.4	12	1
<i>Bubo coromandus</i>	0	0	0	0	0	0	3	0.9	1	0.4	4	0.3
<i>Butastur teesa</i>	4	2.6	5	2.4	5	2.1	6	1.8	1	0.4	21	1.8
<i>Buteo buteo</i>	2	1.3	1	0.5	1	0.4	1	0.3	1	0.4	6	0.5
<i>Buteo rufinus</i>	4	2.6	5	2.4	4	1.6	1	0.3	0	0	14	1.2
<i>Circus gallicus</i>	2	1.3	1	0.5	3	1.2	5	1.5	2	0.8	13	1.1
<i>Circus aeruginosus</i>	1	0.6	3	1.4	8	3.3	15	4.6	7	2.9	34	2.9
<i>Circus macrourus</i>	1	0.6	3	1.4	4	1.6	1	0.3	1	0.4	10	0.9
<i>Circus pygargus</i>	1	0.6	3	1.4	4	1.6	3	0.9	1	0.4	12	1
<i>Clanga clanga</i>	4	2.6	2	0.9	2	0.8	1	0.3	1	0.4	10	0.9
<i>Clanga hastata</i>	1	0.6	1	0.5	1	0.4	2	0.6	4	1.7	9	0.8
<i>Elanus caeruleus</i>	5	3.2	9	4.2	22	9	12	3.6	7	2.9	55	4.7
<i>Falco chicquera</i>	2	1.3	3	1.4	2	0.8	1	0.3	1	0.4	9	0.8
<i>Falco jugger</i>	3	1.9	5	2.4	5	2.1	5	1.5	1	0.4	19	1.6
<i>Falco peregrinus</i>	1	0.6	1	0.5	6	2.5	4	1.2	1	0.4	13	1.1
<i>Falco subbuteo</i>	1	0.6	1	0.5	0	0	1	0.3	0	0	3	0.3
<i>Falco tinnunculus</i>	3	1.9	6	2.8	8	3.3	5	1.5	2	0.8	24	2
<i>Gyps bengalensis</i>	1	0.6	2	0.9	0	0	6	1.8	19	8	28	2.4
<i>Gyps fulvus</i>	20	12.8	32	15	10	4.1	5	1.5	2	0.8	69	5.8
<i>Gyps himalayensis</i>	10	6.4	12	5.6	1	0.4	1	0.3	1	0.4	25	2.1
<i>Gyps indicus</i>	6	3.9	5	2.4	4	1.6	2	0.6	20	8.4	37	3.1
<i>Hieraaetus pennatus</i>	2	1.3	2	0.9	6	2.5	6	1.8	6	2.5	22	1.9
<i>Ictinaetus malaiensis</i>	0	0	0	0	0	0	2	0.6	0	0	2	0.2
<i>Milvus migrans</i>	2	1.3	4	1.9	36	14.8	65	19.7	46	19.3	153	12.9
<i>Neophron percnopterus</i>	15	9.6	43	20.2	8	3.3	14	4.2	25	10.5	105	8.9
<i>Nisaetus cirrhatus</i>	0	0	0	0	1	0.4	2	0.6	1	0.4	4	0.3
<i>Otus bakkamoena</i>	1	0.6	1	0.5	3	1.2	6	1.8	2	0.8	13	1.1
<i>Pandion haliaetus</i>	1	0.6	1	0.5	4	1.6	9	2.7	6	2.5	21	1.8
<i>Pernis ptilorhynchus</i>	1	0.6	1	0.5	6	2.5	15	4.6	7	2.9	30	2.5
<i>Sarcogyps calvus</i>	3	1.9	1	0.5	0	0	3	0.9	5	2.1	12	1
<i>Spilornis cheela</i>	0	0	0	0	3	1.2	6	1.8	5	2.1	14	1.2
<i>Strix ocellata</i>	0	0	0	0	1	0.4	2	0.6	1	0.4	4	0.3
<i>Tyto alba</i>	1	0.6	1	0.5	3	1.2	5	1.5	2	0.8	12	1
Total	156	100	213	100	244	100	330	100	239	100	1182	100
Total Species	36		38		36		41		37		43	

Raptor morbidity, mortality, and post-release survival tracking: rehabilitation outcomes from a wildlife rehabilitation centre in Cyprus

Chorobnosť, úmrtnosť a sledovanie prežívania dravých vtákov po vypustení: výsledky rehabilitácie z centra pre rehabilitáciu voľne žijúcich živočíchov na Cypre

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Abstract: Raptors as apex predators hold an ecologically important position in biological food webs and historically have faced numerous challenges. Wildlife rehabilitation centres provide an opportunity to understand the regional threats to local raptors. This study details the admissions and recoveries of wild raptors admitted to the Wildlife Rescue and Rehabilitation Center in Northern Cyprus between 2016 and 2022. A total of 1,101 raptors were admitted, comprising 22 species and three families, with a mean rehabilitation success rate of 42.6%. The most common species admitted were common kestrels (*Falco tinnunculus*) (44.1%), little owls (*Athene noctua*) (22.8%), and western barn owls (*Tyto alba*) (11.6%). The prevalent causes of admission were trauma (unknown) (27.2%), orphaned/abandoned (22.6%), and collision (11.9%). Post-release survival rates averaged 368 days \pm 407 SD (median = 183, range 2–1,177). Six birds [four long-legged buzzards (*Buteo rufinus*), one European honey buzzard (*Pernis apivorus*) and one northern goshawk (*Astur gentilis*)] were GPS tracked following recovery, and their average survival time was 319 days \pm 334 SD (median = 184, range 18–847, and one still transmitting). Additionally, one Bonelli's eagle (*Aquila fasciata*) and four long-legged buzzards were fitted with either a tail-mounted or leg-mounted VHF radio transmitter, which were less successful, with only the Bonelli's eagle being tracked away from its release site. Post-release survival indicates that the release assessment of individuals is professionally managed, while the rehabilitation success rates demonstrate that the centre is delivering effective treatment and care.

Abstrakt: Dravé vtáky ako vrcholoví predátori zaujímajú ekologicky dôležité miesto v biologických potravných reťazcoch a historicky boli vystavené mnohým výzvam. Centrá na rehabilitáciu voľne žijúcich živočíchov poskytujú príležitosť pochopiť regionálne hrozby pre miestne dravé vtáky. Táto štúdia podrobne opisuje prijatia a zotavenia voľne žijúcich dravých vtákov prijatých do Centra na záchranu a rehabilitáciu voľne žijúcich živočíchov na Severnom Cypre v rokoch 2016 až 2022. Celkovo bolo prijatých 1101 dravých vtákov, zahŕňajúcich 22 druhov a tri čeľade, s priemernou úspešnosťou rehabilitácie 42,6 %. Najčastejšie prijatými druhmi boli sokol myšiár (*Falco tinnunculus*) (44,1 %), kuvik obyčajný (*Athene noctua*) (22,8 %) a plamienka driemavá (*Tyto alba*) (11,6 %). Najčastejšími dôvodmi prijatia boli úrazy (neznáme) (27,2 %), osirelosť/opustenie (22,6 %) a kolízia (11,9 %). Miera prežitia po vypustení bola v priemere 368 dní \pm 407 SD (medián = 183, rozsah 2–1177). Šesť vtákov [štyri myšiaky hrdzavé (*Buteo rufinus*), jeden včelár lesný (*Pernis apivorus*) a jeden jastrab veľký (*Astur gentilis*)] bolo po zotavení sledovaných pomocou GPS vysieláča a ich priemerná doba prežitia bola 319 dní \pm 334 SD (medián = 184, rozsah 18–847, jeden stále vysielal). Okrem toho bol jeden orol jastrabovitý (*Aquila fasciata*) a štyri myšiaky hrdzavé vybavené VHF rádiovým vysieláčom umiestneným na chvoste alebo na nohe, čo bolo menej úspešné, keďže iba orol jastrabovitý bol sledovaný mimo miesta svojho vypúšťania. Prežívanie po vypúšťaní naznačuje, že hodnotenie vypúšťania je realizované profesionálne, zatiaľ čo úspešnosť rehabilitácie demonštruje, že centrum poskytuje účinnú liečbu a starostlivosť.

Key words: birds of prey, recovery rates, satellite and radio tracking, Accipitriformes, Falconiformes, Strigiformes, survival rates

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Introduction

As apex predators, raptors hold an important ecological position and are often used as flagship species to highlight environmental issues (Donazar et al. 2016). Historically, raptors have experienced numerous threats, ranging from direct persecution to indirect effects such as habitat destruction or chemical contamination (O'Bryan et al. 2022). As providers of critical ecosystem services, their position as apex predators means they suffer from biomagnification of pollutants such as polychlorinated biphenyls (PCBs), pesticides (such as insecticides and rodenticides), Diclofen (medication), and heavy metals (like lead and mercury) (Opdam et al. 1986; Green et al. 2004, González-Rubio et al. 2021). This was most notably highlighted by the decline of some raptor populations due to eggshell thinning caused by dichloro-diphenyl-trichloroethane (DDT) exposure (Rodríguez-Jorquera et al. 2017, Kuo et al. 2022). Electrocution and collisions with energy infrastructure, including wind turbines, have also emerged as lethal hazards for migratory raptors (Kouba et al. 2021, Oppel et al. 2021). Concerted international efforts have been made to protect important sites for migratory raptors, recognising over 7,500 as crucial for their conservation (Birdlife Annual Review 2023). Despite these efforts, the conservation status of many raptor species continues to deteriorate, highlighting the urgent need for increased protection measures and awareness to ensure the survival of raptors and the biodiversity they support.

According to recent estimates, 52% of raptors are in decline and 18% threatened with extinction (McClure et al. 2018). Numerous raptor species have recovered from historical population declines through direct conservation initiatives, including reintroductions, habitat restoration, and legislative changes (Jones et al. 1995, Cruz et al. 2018, Nygård et al. 2019). However, many raptor populations are still in decline, which is concerning given the vital role raptors play in ecosystem services

and functioning (McClure et al. 2018). Such population declines can result in top-down trophic cascades, leading to increases in mesopredators and meso-scavengers (Ritchie & Johnson 2009). The consequences of which can lead to population explosions of pest species or epidemiological imbalances of disease reservoir hosts (Prugh et al. 2009, Muñoz-Pedrerros et al. 2016).

In Cyprus, 46 species of raptors have been reported, 13 of which have not been seen in 20 years or can be classed as vagrant species (Flint & Richardson 2024). Twelve of these species are current regular residents or migrant breeders, with the remaining being passage migrants or winter visitors (Flint & Richardson 2024). Three breeding raptor species in Cyprus have become locally extinct, with 3–4 species having population levels which could be classified as precarious (low number of breeding pairs) due to a range of human-induced threats such as habitat loss through urbanisation and agricultural expansion (Flint 2019). Illegal poisoning, often aimed at controlling predator populations for livestock protection, has inadvertently led to a decline in raptor numbers, with non-target species like the griffon vulture (*Gyps fulvus*) and Bonelli's eagle (*Aquila fasciata*) falling victim (Tsiakiris et al. 2021). Trapping and shooting also significantly impact many raptor species (Brochet et al. 2016).

During the early 20th century, individuals began to take and rehabilitate injured and distressed wild animals. These pioneers operated out of their homes, often with makeshift facilities, relying on their instincts and compassion to care and rehabilitate these creatures before returning them to the wild (Williamson 2013). Over the last 50 years, there have been advances in the treatment, housing, rehabilitation and release protocols in the field of wildlife rehabilitation, with the formation of dedicated wildlife rehabilitation programs across the globe, including facilities specialising on specific animal groups (Paterson et al. 2021). One such animal group is birds of prey, or raptors, with resources targeted at their treatment and welfare (including humane euthanasia).

Despite advances in rehabilitation practices, survival outcomes for released raptors remain difficult to assess, underscoring the need for comprehensive post-release evaluation. Rehabilitation facilities often use metal rings to identify released birds, including raptors, but these generally have low recapture rates (Bildstein & Peterjohn 2012, Lutmerding et al. 2012). Radio-tracking enables researchers to monitor released individuals periodically; however, it faces challenges in range, topography and workforce. Satellite tracking, which offers near real-time location and movement data, is potentially the most effective method for tracking raptors. However, it can be the costliest, which makes it prohibitive to many centres and generally results in small sample sizes.

This study reports admission causes and the final outcomes of all raptors admitted to Cyprus's Wildlife Rescue and Rehabilitation Center (WRRRC). Also documented are the recapture events of previously treated and released raptors (2016–2022), including their post-release survival and movements, through ringing, satellite and radio tracking methods.

Materials and Methods

WRRRC was established in July 2016 and now falls under the umbrella organisation, the Cyprus Wildlife Research Institute (CWRI). It is located approximately 10 km north of Nicosia. WRRRC staff rescue and treat any sick, injured, or orphaned wild animal, aiming to return them to the wild. A new admission number is assigned if a patient undergoes subsequent readmissions; however, these admissions are cross-referenced with prior records for continuity and accuracy. Additionally, it has become a sanctuary for any confiscated animal illegally imported or kept in captivity.

This study includes all raptors admitted to the centre from 2016 to 2022. Raptors were collected by the centre team, delivered by the public, or confiscated by government officials. A trained wildlife biologist or veterinarian examined all raptor admissions to determine an animal's condition and whether any specialist interventions were required. All raptors that were successfully rehabilitated were fitted with a metal leg ring and released close to where they were collected (if known) following morphometric measurements, ageing and sexing (if possible). Migratory species that missed their migration window were kept until the next available migration season. Individuals who survived but were not releasable were placed in a purpose-built sanctuary complex.

One Bonelli's eagle and four long-legged buzzards (*Buteo rufinus*) were fitted with a tail-mounted or leg-mounted VHF radio transmitter (Biotrack Inc., UK; model TW-3-10-28). After that, they were tracked daily using a hand-held receiver and binoculars (x10). However, given the poor results and limited workforce, it was decided to use GPS tracking technology to track rehabilitated raptors instead.

Six released raptors [four long-legged buzzards, one northern goshawk (*Astur gentilis*), and one European honey buzzard (*Pernis apivorus*)] were fitted with solar-powered GPS-GPRS telemetry transmitters (Manufacturer – Ornitela, Lithuania, Models OrniTrack-20-4G, OrniTrack-25-4G, OrniTrack-30-4G) which possess GPS modules for receiving GPS data and transmitting via the 4G cellular system. Transmitters were fitted to the six raptors using a permanent 5-mm-wide Teflon tape backpack wing harness described by Thaxter et al. (2014). Individual devices' data recording and duty cycles were optimised according to solar irradiance capture and battery charging levels. Location data was downloaded as “csv.” files and filtered to optimise figure presentations, with at least the first location for each day shown. When the data was required to highlight a specific incident or behaviour, that specific data was left unfiltered. When location data did not show individual movement for 24–48 hours, the location was visited (only possible for locations in Cyprus) to determine the reason and retrieve any carcasses for necropsy. Device failure was determined if the device suddenly stopped providing location data for no logical reason (i.e., previous adequate battery levels, location altitude/travel speed). All map figures were constructed using ArcGIS Pro version 3.5 (Esri, USA).

Results

Species admissions

A total of 1,101 raptors were admitted between 2016 and 2022, comprising 22 species from 3 families (Table 1). The three most common raptor species admitted were common kestrels (*Falco tinnunculus*) 44.1%, little owls (*Athene noctua*) 22.8% and western barn owls (*Tyto alba*) 11.6%, accounting for 78.6% of all raptor admissions. Eleven of the twelve regular resident or migrant breeding species (except the griffon vulture) have also been admitted to the centre.

Reason for admission

The three most common reasons for admission were trauma (unknown cause) 27.2%, orphaned/abandoned 22.6%, and collisions (car, building, or other) 11.9%

Tab. 1. Total counts of admission reasons and outcomes for all raptor species admitted to the Wildlife Rescue and Rehabilitation Center between 2016 and 2022. Overall percentages for each admission reason and outcome are also provided.

Tab. 1. Celkový počet dôvodov prijatia a výsledky všetkých druhov dravých vtákov prijatých do Centra pre záchranu a rehabilitáciu voľne žijúcich živočíchov v rokoch 2016 až 2022. Uvedené sú aj celkové percentuálne podiely pre každý dôvod prijatia a výsledok.

Species	Admission Reasons												Final Outcomes					
	Collisions	Dog/Cat Predation	Gunshot	Trapped/Relocation	Captivity	Born in Centre	Orphaned/Abandoned	Infectious Disease	Nutritional	Toxicosis	Neurological	Unknown Trauma	Undetermined/Other	Released	Sanctuary	Died / Euthanised	Total Admissions	Success Rate %
barn owl (<i>Tyto alba</i>)	27	1	2	17	1	1	19	10	4	1	0	32	13	43	12	73	128	33.6
black kite (<i>Milvus migrans</i>)	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	100
Bonelli's eagle (<i>Aquila fasciata</i>)	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1	2	50
common buzzard (<i>Buteo buteo</i>)	1	0	7	1	2	0	0	1	1	1	0	4	3	6	5	10	21	28.6
common kestrel (<i>Falco tinnunculus</i>)	40	3	16	16	48	5	138	35	12	1	2	136	34	240	35	211	486	49.4
Cyprus scops-owl (<i>Otus cypricus</i>)	3	2	0	3	0	0	5	0	0	1	0	10	3	9	2	16	27	33.3
Eleonora's falcon (<i>Falco eleonora</i>)	0	0	0	0	0	0	0	0	2	0	0	1	0	1	0	2	3	33.3
Eurasian hobby (<i>Falco subbuteo</i>)	0	0	1	0	0	0	0	2	2	0	0	5	0	3	2	5	10	30
Eurasian sparrowhawk (<i>Accipiter nisus</i>)	4	0	8	2	0	0	0	0	0	0	1	12	1	3	3	22	28	10.7
European honey-buzzard (<i>Pernis apivorus</i>)	1	0	2	0	2	0	0	2	0	0	0	7	1	2	1	19	15	13.3
hen harrier (<i>Circus cyaneus</i>)	1	0	10	0	1	0	0	0	0	0	0	10	0	9	1	5	22	40.9
little owl (<i>Athene noctua</i>)	41	11	1	30	5	0	83	8	6	0	6	43	17	121	23	107	251	48.2
long-legged buzzard (<i>Buteo rufinus</i>)	1	0	5	5	1	4	0	1	0	0	0	6	0	11	5	7	23	47.8
merlin (<i>Falco columbarius</i>)	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	2	0
Montagu's Harrier (<i>Circus pygargus</i>)	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	4	4	0
northern goshawk (<i>Astur gentilis</i>)	1	0	4	1	0	0	0	0	0	0	0	0	0	2	2	2	6	33.3
northern long-eared owl (<i>Asio otus</i>)	7	0	1	3	1	0	4	2	5	0	2	14	2	8	5	28	41	19.5
pallid harrier (<i>Circus macrourus</i>)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0
peregrine falcon (<i>Falco peregrinus</i>)	1	0	3	0	2	0	0	3	0	0	0	7	0	4	1	11	16	25
red-footed falcon (<i>Falco vespertinus</i>)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
short-eared owl (<i>Asio flammeus</i>)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
western marsh harrier (<i>Circus aeruginosus</i>)	0	0	2	1	0	0	0	1	0	1	0	7	0	5	3	4	12	41.7
Total	131	17	64	80	64	10	249	65	32	5	11	299	74	469	100	532	1101	42.6
Percentage	11.9	1.5	5.8	7.3	5.8	0.9	22.6	5.9	2.9	0.5	1.0	27.2	6.7	42.6	9.1	48.2		

(for each species admission percentages, see Supplementary Table S1). Other common reasons for admission were trapped/relocation (7.3%), infectious diseases (5.9%), gunshot (5.8%), and captive confiscations (5.8%). However, certain injuries predominantly affected specific species; for example, dog/cat predations were primarily seen in the smaller owl species, with little owls providing the most admissions for this category. For northern goshawks and hen harriers (*Circus cyaneus*), injuries from gunshots made up the highest proportion of their admissions at 66.7% and 45.5%, respectively. Most collision-related admissions were attributed to vehicle collisions, accounting for 72.5% of the total collision cases. Notably, 93.7% of these incidents involved five species only (Table 2).

Final outcomes

The total number of birds released from the centre between 2016 and 2022 was 469 (42.6%). One hundred birds were deemed non-releasable and transferred to the sanctuary (9.1%). The remaining 532 raptors (48.3%) either died or were euthanised. The species with the highest success rates (excluding species with < 10 individuals) were common kestrel (49%), little owl (48%), long-legged buzzard (48%), western marsh harrier (*Circus aeruginosus*) (42%), and hen harrier (41%).

Ringed recaptures / Resightings

There were seven ringing recaptures or resightings during the study period, a recapture rate of < 1% (Table 3). The time between release and resighting ranged from 2 to 1,177

Tab. 2. Comparison of vehicular and non-vehicular collision admissions. The top five species admitted with collision-related injuries.

Tab. 2. Porovnanie prípadov prijatia v dôsledku zrážky s vozidlom a inej zrážky. Päť najčastejších druhov prijatých v dôsledku zranenia spôsobeným zrážkou.

	Collision (non-vehicle)	Collision (vehicle)	Total	% vehicle collisions
little owl	7	34	41	82.9
barn owl	6	21	27	77.8
northern long-eared owl	2	5	7	71.4
common kestrel	13	27	40	67.5
Cyprus scops owl	1	2	3	66.7
Total	29	89	118	

days, which is related to a little owl and common kestrel, respectively (Table 3). A juvenile peregrine falcon (*Falco peregrinus*) released in the Karpaz peninsula was later confiscated by the Royal Society for the Conservation of Nature in Jordan after being illegally trapped near Aqaba in southern Jordan. The bird was subsequently released at the Rift Valley of Jordan close to the Dead Sea coast. In addition to the cases shown in Table 3, a long-legged buzzard rescued after being kept in captivity for two years was released, only for the centre to be called again as the bird was perched in a garden close to WRRC. It was decided that this bird had become imprinted and could not be released back into the wild. It was consequently readmitted to the sanctuary to later become part of the long-legged buzzard breeding program. Another released long-legged buzzard did not fare so well, as following its release, it was electrocuted after perching on some overhead power lines.

Tracking results

The GPS tracking produced a variety of outcomes (Table 3), the summaries of which are given below. The average time at large from the GPS-tracked birds was 319 days ± 334 SD (median = 184, range 18–847 days).

European honey buzzard (RC2363): Following release on 29/11/2021 from WRRC in Northern Cyprus, the bird travelled south-easterly across Cyprus and crossed the Mediterranean Sea before reaching land in Israel. This southerly directed journey continued across Israel and into Saudi Arabia, where the transmissions ceased after 18 days just south of Al Wajh, in north-west Saudi Arabia (Fig. 1).



Fig. 1. Post-release positions (yellow circles) of the European honey buzzard (RC2363) released from Northern Cyprus (R) and monitored to the Red Sea coast of Saudi Arabia, where transmissions ceased (E) on 17/12/2021.

Obr. 1. Pozície včelára lesného (RC2363) po vypustení (žlté body) zo severného Cypru (R) a sledovaného až po pobrežie Červeného mora v Saudskej Arábii, kde 17. 12. 2021 došlo k prerušeniu prenosu (E).

Northern goshawk (RC2443): This bird was released on 30/4/2022, close to the village of Koruçam where it was found initially (Fig. 2). As this species is a resident in Cyprus it remained in the general vicinity, holding a territory where it was released for 4 months never moving further than a few kilometres at any one time (marked A in Fig. 2). It then moved 5 km south, where it remained for 18 days (marked B in Fig. 2), before returning the previous area. During the following week, it spent time shuttling between the two sites, spending a couple of days at a time within each location. During the final 5 days of the transmission, the bird moved to a new area near Geçitköy reservoir, where it was later found dead (marked C in Fig. 2).

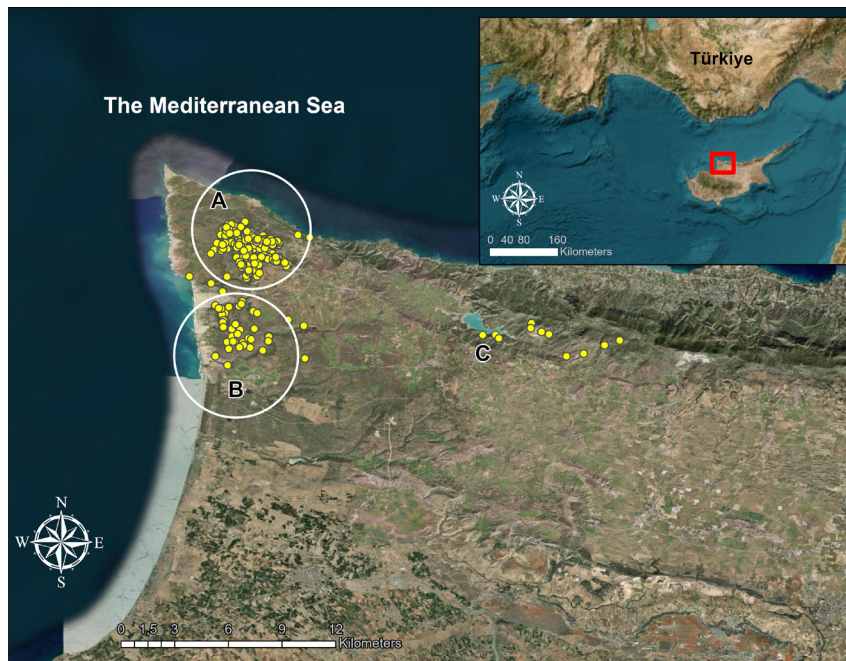


Fig. 2. Post-release positions (yellow circles) of areas (A and B) inhabited by the northern goshawk (RC2443) in the region of Cape Kormakitis. It was released in area A on 30/4/22, and was later found dead on 9/10/22 at location C.

Obr. 2. Pozície sledovaného jastraba veľkého (RC2443) po vypustení (žlté body) v oblastiach (A a B) v regióne Cape Kormakitis. Jedinec bol vypustený v oblasti A dňa 30. 4. 2022. Neskôr, 9. 10. 2022 bol jedinec nájdený uhynutý na mieste C.

The bird may have been shot, as the birds' movements ceased following a designated official hunting day. The carcass and transmitter were recovered a few days later, but only the bird's wings and legs remained, probably due to post-mortality foraging by scavengers (Fig. 3).

Long-legged buzzards: Four individuals have been tracked to date, two died after 65 and 205 days respectively (Table 3; Figs. 4 and 5), one ceased to transmit locations on 11/7/2024 and the final one, of which at the time of writing 28/2/2025, was still at large, with transmitter functioning (Table 3; Figs. 6 and 7).

Long-legged buzzard (RC2321): Released from the rehabilitation centre on 15/11/21 and remained in the Kyrenia mountains close to the release site for three days. It then flew for 30 km southerly and spent three days close to Tamassos reservoir. It then flew south a further 30 km before stopping and spending two days near the village of Pentakomo. Over the next few days, it flew east; then northeast a total of 70 km before settling in an area between the villages of Boğaziçi and Mormenekşe (area marked with a black box in Fig. 4). It remained in this location (except for a couple of brief excursions to Larnaca and Kaleburnu) until its death (reason unknown) on 8/6/2022.



Fig. 3. The northern goshawk (RC2443) tracked post-release for 162 days. The carcass had been scavenged, with only wings and legs remaining.

Obr. 3. Jastrab veľký (RC2443) sledovaný 162 dní po vypustení. Kadáver bol nájdený obžratý, zostali len krídla a nohy.

Tab. 3. Successful release and recapture events recorded at the Wildlife Rescue and Rehabilitation Center between 2016 and 2022.
Tab. 3. Úspešné prípady vypustenia a opätovného odchyту zaznamenané v Centre pre záchranu a rehabilitáciu voľne žijúcich živočíchov v rokoch 2016 až 2022.

Species and mark type	ID No	Admission Date	Release Date	Recovery/ Final Date	Survival Days	Notes	
						Admission Reason	Resighting details
Metal ringed							
common kestrel	65	23.2.2018	10.7.2018	13.10.2020	826	Found in a garage, feather damage, probably kept captive.	Readmitted after being shot and later died.
little owl	1121	30.4.2020	19.6.2020	21.6.2020	2	Admitted as juvenile/orphan.	Found dead (skull injury).
western barn owl	1423	4.7.2020	15.7.2020	16.11.2020	124	Sticky substance on feathers.	Found dead.
common kestrel	1462	1.1.2017	20.4.2017	10.7.2020	1177	First admission fractured wing.	See second admission reason.
—	—	10.7.2020	23.2.2021	—	—	Second admission, infection weak/ underweight.	
peregrine falcon	2093	8.6.2021	15.11.2021	10.2.2022	87	Admitted due to a collision, released in Karpaz.	Confiscated from trappers in Jordan.
long-legged buzzard	2866	6.6.2022	25.6.2022	17.9.2022	84	Rescued from irrigation pond, released Doganci.	See second admission reason.
GPS tracked							
European honey buzzard	2363	29.9.2021	29.11.2021	17.12.2021	18	Confiscated, poor condition.	Ceased transmitting.
northern goshawk	2443	28.11.2021	30.4.2022	9.10.2022	162	Ulna's fractured, shot gun pellets	Found dead possibly shot
long-legged buzzard	2321	3.9.2021	15.11.2021	8.6.2022	205	Emaciated, high ectoparasite load.	Found dead after release.
long-legged buzzard	2881	BP*	7.7.2022	20.7.2022	13	Born in sanctuary.	See second admission reason.
—	—	20.7.2022	23.7.2022	13.9.2022	52	Rescued from sea and later released.	Found dead (shot).
long-legged buzzard	2866**	17.9.2022	4.11.2022	still at large	847+	2nd admission, shotgun pellets, fractured ulna and femur.	Still transmitting
long-legged buzzard	3262	15.10.2022	4.11.2022	11.7.2024	615	Rescued from irrigation pond. No major injuries.	Ceased transmitting, device lost power.
Radio tracked							
Bonelli's eagle	376	20.11.2018	20.12.2018	12.7.2019	204	Trapped in partridge breeding cages.	Later tracked to nesting location.
Mean days at large					368		

*breeding program identifies an individual born in the centre. **An end date of 28/2/2025 was used to calculate the survival days for the long-legged buzzard (2866).

Long-legged buzzard (RC2881): On its release from the rehabilitation centre (07/7/2022), it flew north to the coastline before heading easterly to the tip of the Karpaz peninsula. Next, it flew a few kilometres west to the village of Dipkarpaz, where it remained for 8 days (green circles, Fig. 5). On the morning of 20/7/2022 (yellow circles, Fig. 5), it flew back to the tip of the Karpaz peninsula and out of the Khleides Islands. Tracking data showed its GPS locations and altitude to be in the sea and drifting in a south-westerly direction (marked A in Fig. 5). Approximately three hours later, the bird was rescued (marked B in Fig. 5) and returned to the rehabilitation centre, where it was observed for a few days before its second release on 23/7/2022. Following its second release, it again returned to Dipkarpaz village (green circles, Fig. 5), where it died 52 days later after being shot (x-ray confirmation).

Long-legged buzzard (RC2866): Released from the rehabilitation centre on 4/11/2022, and over the next few days, it first flew south and then west, before reaching Güzelyurt on 7/11/2022. After spending approximately two months in the agricultural fields surrounding Güzelyurt (area B in Fig. 6), it flew south to the foothills of the Troodos mountains (area A in Fig. 6), where it remained for the next two weeks before returning to the Güzelyurt region (24/1/23). During the next three months, it shuttled between these two regions, spending 1 to 6 days at each (areas labelled A and B in Fig. 6). From 29/4/22, the bird flew from Güzelyurt back to Troodos, where it remained until the autumn. On 1/10/23, the bird flew back to Güzelyurt until it returned to Troodos on 13/11/2023. This bird has continued this movement pattern while the device still functions.

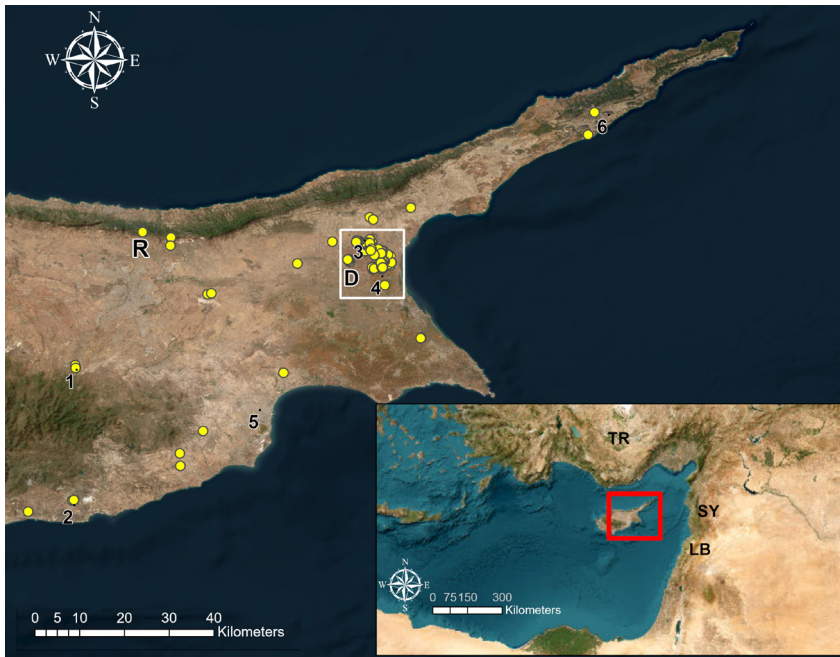


Fig. 4. Long-legged buzzard (RC2321) post-release positions (yellow circles) after released from the Wildlife Rescue and Rehabilitation Center (R) on 15/11/21. The white square encompasses the area where the bird spent 95% of its time. Finally being found dead (D) on 8/6/22. The bird visited the following locations described in the discussion: 1 = Tamassos Reservoir, 2 = Pentakomo, 3 = Boğaziçi, 4 = Mormenekşe, 5 = Larnaca and 6 = Kaleburnu.

Obr. 4. Pozície myšiaka hrzdavého (RC2321) po vypustení (žlté body) z Centra pre záchranu a rehabilitáciu voľne žijúcich živočíchov (R) 15. 11. 2021. Biely štvorec zahŕňa oblasť, kde vták strávil 95 % svojho času, až kým bol 8. 6. 2022 nájdený mŕtvy (D). Vták navštívil nasledujúce miesta opísané v diskusii: 1 = vodná nádrž Tamassos, 2 = Pentakomo, 3 = Boğaziçi, 4 = Mormenekşe, 5 = Larnaca a 6 = Kaleburnu.

Long-legged buzzard (RC3262): Released from the WRRC on 4/11/2022, after which, similar to the previous bird, it flew south and west before settling on 12/11/2022 near the village of Gaziveren. It remained in the agricultural fields surrounding this village for the

next three months. On 10/2/2023, the bird flew 18 km south to the foothills of the Troodos mountains and over the next two weeks, it spent time shuttling between these two locations (marked A and B in Fig. 7), spending 1 to 3 days at each location. After returning to Troodos

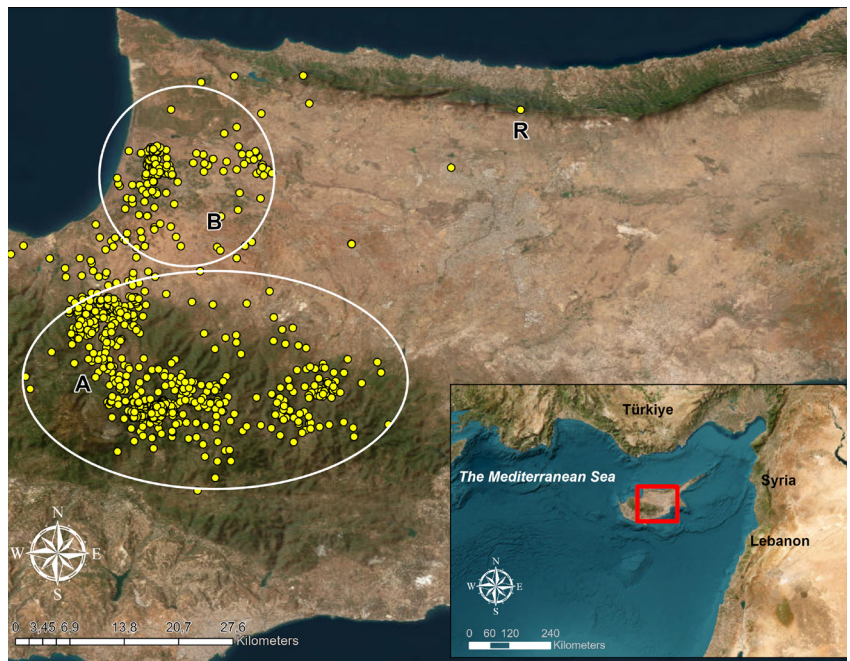


Fig. 5. Long-legged buzzard (RC2881), post-release positions (green circles) after release from the Wildlife Rescue and Rehabilitation Center (R) on 7/7/22. Movements (yellow circles) on 20/7/22 before and during the sea rescue. The bird entered the water at location A and was rescued at location B. Movements following the 2nd release on 23/7/22 from the centre (R) (blue circles), the bird returned to Dipkarpaz, where on 13/9/2022 was found dead (shotgun wounds).

Obr. 5. Pozície myšiaka hrzdavého (RC2881) po vypustení (zelené body) z Centra pre záchranu a rehabilitáciu (R) dňa 7. 7. 2022. Pohyby (žlté body) dňa 20. 7. 2022 pred a počas záchranu na mori. Vták vošiel do vody v mieste A a bol zachránený v mieste B. Pohyby po druhom prepustení 23. 7. 2022 z centra (R) (modré body), vták sa vrátil do Dipkarpazu, kde bol 13. 9. 2022 nájdený mŕtvy (zranenia po brokovnici).

Fig. 6. Long-legged buzzard (RC2886), post-release positions (yellow circles) 4/11/22 – 19/11/23, after release from the Wildlife Rescue and Rehabilitation Center (R), the bird predominantly spent most of its time in either the forested foothills of the Troodos mountains (A) or agricultural fields around Güzelyurt (B). This pattern of movement continues, with the device still transmitting.

Obr. 6. Pozície myšiaka hrdzavého (RC2886) po vypustení 4. 11. 2022 – 19. 11. 2023 (žlté body) z Centra pre záchranu a rehabilitáciu voľne žijúcich živočíchov (R). Vták trávil väčšinu času v zalesnených výbežkoch pohoria Troodos (A), alebo na poliach v okolí Güzelyurtu (B). Tento pohybový vzorec pokračuje, pričom zariadenie stále vysiela signál.

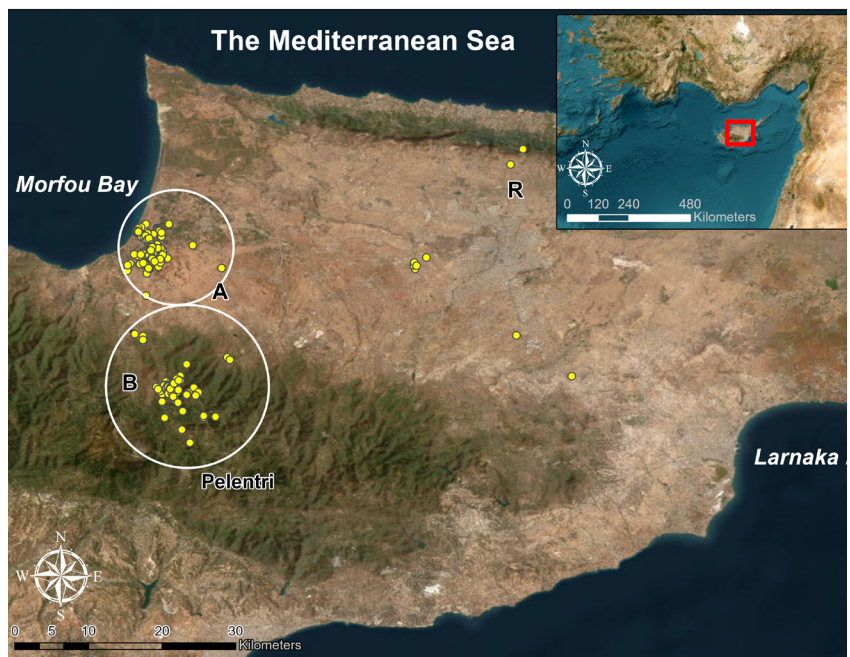


on 25/2/23, the bird remained in this region for the next 23 days before resuming the shuttling behaviour between the two locations with slightly extended stays (1–10 days) between shuttling events. On 2/7/2023, the bird flew from Troodos to Gaziveren, where it remained almost

two months, before resuming the shuttling behaviour between the two regions until 21/11/23. The exceptions to these two central locations were a couple of trips to Astromeritis and south Nicosia, where the bird remained for one and two days, respectively. The bird continued to

Fig. 7. Long-legged buzzard (RC3262), post-release positions (yellow circles) 4/11/22–11/7/24, after release from the Wildlife Rescue and Rehabilitation Center (R), the bird pre-dominantly spent most of its time either in agricultural fields around the village of Gaziveren (A) or the forest foothills of the Troodos mountains (B). The bird continued to inhabit the two main areas (A and B) until the device lost power on 11/7/2024 near the village of Pelentri.

Obr. 7. Pozície myšiaka hrdzavého (RC3262), 4.11.2022 – 11.7.2024 (žlté body) po prepustení z Centra pre záchranu a rehabilitáciu voľne žijúcich živočíchov (R). Vták trávil väčšinu času na poliach v okolí dediny Gaziveren (A), alebo v lesnatých podhorách pohoria Troodos (B). Vták naďalej obýval tieto dve hlavné oblasti (A a B), až kým sa zariadenie nevybilo 11/7/2024 v blízkosti dediny Pelentri.



inhabit the two main areas (A and B) until the device lost power on 11/7/2024 near the village of Pelentri in zone B (Fig. 7).

Radio tracking results

The results from the radio-tracked birds were generally poor, with only the Bonelli's eagle being tracked for more than a couple of days (see Table 3 for details). Following its release on 20/12/2018, the Bonelli's eagle flew south towards Haspolat, then took an easterly direction and spent a couple of days around the village of Vadili in the Mesaoria plain. By January, his location had shifted to the southern slopes of the west part of the Kyrenia range, and he had settled around the village of Göçeri, where he was observed with his mate by mid-January. In late February, their nesting site was discovered in a rock crevice on the southern face of the Pentadactylos range (Fig. 8).

The nest was monitored three times using a drone: 26/2/2019 February – 2 eggs were present, 19/4/2019 April – 2 chicks were active in the nest, and finally on 26/5/2019 May – there was only one nestling left in the nest. On the final day of nest observation, the female was flying with another bird, potentially the other fledgling and not the tracked male, as no signals were detected from the flying couple. The final signal was detected in July, from a nearby quarry 2 km west of the village of Göçeri, with

no sightings of the bird, leading us to believe that the transmitter was lost, possibly through the moulting of its tail feathers.

Discussion

Threats to wildlife populations, raptors included, are diverse and encompass both natural and non-natural hazards. Raptor populations can be critical ecological indicators for ecosystem health, highlighting an array of factors which can endanger both wildlife and humans alike. Identifying specific threats to raptor populations can aid conservation efforts by targeting those particular threats through legislation, enforcement and education (Arroyo & Ferreiro 1997, Sarasola et al. 2018). This study constitutes the first analysis of raptor mortality or morbidity cases admitted to a rehabilitation facility in Cyprus. Descriptive studies related to wildlife mortality and morbidity provide essential insights into the threats wild animals face. The major causes of admission found in this study are also those commonly reported in studies from other countries. Wendell et al. (2002) reported trauma as the major reason for raptor admissions to Colorado State University Veterinary Teaching Hospital, together with numerous other studies stating it as the primary reason for admission (Molina-López et al. 2011, Montesdeoca et al. 2016, Cococcetta et al. 2022,



Fig. 8. Radio tracking positions of Bonelli's eagle (RC0376) from its release site at the Wildlife Rescue and Rehabilitation Center on 20/12/18 through the vicinity of the villages of Haspolat, Vadili and Göçeri and finally to its later discovered nesting location in February 2019. The final location, 2 km west of Göçeri village, was recorded on 12/7/2019.

Obr. 8. Pozície radiovo sledovaného orla jastrabovitého (RC0376) (od miesta vypustenia žlté body) v Centre pre záchranu a rehabilitáciu voľne žijúcich živočíchov 20. 12. 2018 cez okolie obcí Haspolatu, Vadili a Göçeri až po miesta hniezdenia, ktoré bolo objavené vo februári 2019. Konečná poloha, 2 km západne od obce Göçeri, bola zaznamenaná 12. 7. 2019.

Pahl 2024). Admissions of orphaned or abandoned birds were the second most frequent reason (22.6%) for admission and are usually seasonal, principally occurring during the spring and summer months. However, they can place enormous pressure on wildlife rehabilitation facilities due to the considerable time demands on those caring for young orphaned or abandoned chicks (Molina-López et al. 2017). Nevertheless, well-intentioned public members can confuse recently fledged, poorly flying individuals with orphaned birds, which can elevate the number of admissions, with those individuals requiring no rehabilitation. Public education initiatives can help inform communities regarding best practices when dealing with orphaned individuals or nestlings.

The most frequently admitted species to the centre were common kestrel, little owl, and western barn owl, amounting to over 75% of all admissions. This is to be expected given their high population levels in Cyprus and their propensity to nest and live near human agropastoral landscapes (Tomé 2011, Flint & Richardson 2024). Gunshot wounding, saw common kestrels as the most frequent species admitted; however, the next most frequent were hen harrier and Eurasian sparrowhawk (*Accipiter nisus*) respectively. These levels are unexpected when considering neither is a common species in Cyprus. One of the main reasons for this is that little owls and western barn owls, typically the most common admissions, are nocturnal in their habits, significantly reducing the likelihood of being shot. This was also seen in a study from Central Italy, where no nocturnal raptors were admitted as a result of gunshot wounds (Cococchetta et al. 2022).

As seen in many Mediterranean countries, Cyprus has a tradition of bird trapping, predominantly using glue or nets to trap migratory songbirds (Bhattacharya 2016, Brochet et al. 2016, Sebastianelli et al. 2020). As with most trapping methods they tend to be indiscriminate in the species they trap, therefore a number of those admitted to the centre were those rescued from glue traps, which required intensive cleaning to remove glue residues, frequently also causing extensive feather damage, which sometimes required veterinary intervention (pulling feathers under anaesthesia) and a long period of rehabilitation.

Toxicosis and infectious diseases, often through the lack of specialist equipment and difficulties in diagnosis, are commonly difficult to identify and are generally under-represented in many wildlife morbidity and mortality studies. That is probably the case here, as with the establishment of any new wildlife rehabilitation facility there is a steep learning curve, generally involving

primarily learning on the job, especially in this case when there is little or no local expertise to draw from when dealing with a wide variety of taxa (Wendell et al. 2002, Panter et al. 2022).

Post-release survival

One of the main challenges for wildlife rehabilitation is understanding their post-release survival. For birds of prey, as apex predators, their visual acuity and flying agility are paramount to their survival. Therefore, all individuals before release are placed in the centre's largest indoor aviary and tested with live prey (mice, rats, or quail as appropriate for the species) to ascertain their suitability for release. Low re-encounter levels of conventionally ringed non-targeted raptors, of between 2–10% (Bildstein & Peterjohn 2012, Lutmerding et al. 2012), led to the use of radio or GPS tracking devices to understand the post-release survival. Radio-tracking was only successfully deployed on a single Bonelli's eagle, unveiling a previously unknown nesting location for the species. All other radio tracking (long-legged buzzards) was less successful, with individuals being lost after only a day or two. The reasons for this are possibly related to the limited suitability of the species for such tracking, the limited workforce, and the terrain involved. The radio tracking devices had an estimated range of ca 20 km, and given the distances these birds can travel post-release, they can quickly move out of range. Mountain ranges can also lead to poor tracking results, requiring multiple personnel to improve coverage. Following these early radio-tracking attempts, satellite tracking devices provided far greater post-release information. With almost real-time location and movement information, and significantly reduced workforce requirements to track the animal, it was even possible in one incident to enable the recovery of a long-legged buzzard from the sea.

Post-release survival of the GPS-tracked birds in this study averaged 319 days, which far exceeds the accepted 4–6 weeks of post-release period used to ascertain the successful survival of an individual bird in the wild (Duke & Redig 1981, Martell et al. 1991). From the acquired tracking data, the rehabilitated birds from the WRRC were fit for release, demonstrating the ability to travel long distances and survive for extended periods in the wild. This implies that rehabilitation methods utilised at the WRRC prepared the birds to a level of fitness required to survive in the wild. Thus, it highlights the importance of rehabilitation centres in preparing injured or sick raptors for survival in the wild. In the case of locally threatened species, they

can provide essential additions to the breeding population (Rozsypalová et al. 2024).

Only one bird failed to meet this criterion, a juvenile European honey buzzard released relatively late in the season for this migratory species. However, due to the relative difficulty in keeping this species in captivity, mild weather forecast and the fact that juvenile honey buzzards do not make return spring northerly migrations in their second and sometimes third year (Strandberg et al. 2012), it was decided best to release this bird rather than wait until the subsequent autumn. The transmission ceased after 19 days during which the bird migrated from Cyprus, across the Mediterranean Sea to Israel and later, to the Red Sea coast. Transmission termination could have been due to a lack of or blocked GSM, although this is likely temporary. Given that the cessation of transmission signal was not temporary, it is likely to be due to a device or transmission malfunction (Monti et al. 2018), because if the bird had died, multiple transmissions would have been received from the same location, so the fate of this individual will remain unknown. All other GPS-tracked individuals survived beyond the prescribed six-week period, with one long-legged buzzard still at large some 2.5 years later.

This study provides the first comprehensive insight into the threats affecting raptor populations in Cyprus through the lens of a wildlife rehabilitation facility. The successful rehabilitation of raptors is particularly evident in its structured release procedures and post-release tracking results, demonstrating that with adequate care, rehabilitated birds can survive extended periods in the wild. These outcomes point to such facilities' value and importance in monitoring specific threats, public education, and investment in diagnostic capabilities. Ultimately, this study contributes to a broader understanding of the dynamic threats facing raptors in Cyprus and the efficacy of rehabilitation centres in mitigating these risks. Strengthening data collection, refining release strategies, and fostering awareness among the public and policymakers will be key to ensuring the long-term survival of these iconic avian predators.

Ethics Approval

The Department of Environmental Protection in Northern Cyprus authorised all raptor interactions in this study. Handling and rehabilitation activities were carried out under official protocols (No. 116/01/7-154) issued by the relevant environmental authorities, which include authorisation for wildlife rehabilitation, and extend to handling, providing medical treatment, ringing and

tracking device attachments. Where recovery was deemed unfeasible due to the severity of injury or illness, euthanasia was performed following ethical and legal guidelines.

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Wintering raptors in lowland farmland of north-western Italy: a second distance sampling survey twenty years later

Zimovanie dravých vtákov v nížinnej poľnohospodárskej krajine severozápadného Talianska: druhé líniové vzorkovanie, dvadsať rokov neskôr

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Abstract: Diurnal raptors and the great grey shrike (*Lanius excubitor*) wintering in the lowland farmland of north-western Italy were surveyed again after 20 years, during the winters of 2020/2021 and 2021/2022. Data were collected using roadside car transects, and perpendicular distances of birds from the transect lines were recorded to estimate wintering raptor densities. Ten species (9 raptors) were observed, but only two species, the common buzzard (*Buteo buteo*) and the common kestrel (*Falco tinnunculus*), were recorded frequently enough to allow reliable density estimates. Extensive rice fields in the north-eastern part of the study area supported high densities of common buzzards, with estimates ranging between 1 and 2 individuals per km². Although occurring at lower densities (~0.5 individuals per km²), the common kestrel showed a broader habitat tolerance and appeared less dependent on specific agricultural landscapes. The estimated wintering population of common buzzards in the lowland farmland of the Piemonte region, an area covering approximately 5,700 km², was slightly higher than that recorded 20 years earlier, ranging between 4,000 and 5,000 individuals. For the common kestrel, the estimated wintering population in the same area was around 2,500 individuals (1,800–3,500). However, the total wintering populations of both species in the whole region were certainly much larger, because they are also widespread during winter in hilly and mountainous areas. Overall, the results highlighted the importance of rice fields for wintering common buzzards, suggested stability in the raptor community, and advocated for broader adoption of distance sampling methods for effective large-scale bird surveys.

Abstrakt: Po 20 rokoch bolo v poľnohospodárskej nížine severozápadného Talianska opäť sledované zimovanie dravých vtákov a strakoša veľkého (*Lanius excubitor*). Výskum prebiehal počas zím 2020/2021 a 2021/2022. Údaje boli zbierané metódou cestných transektov. Hustota zimujúcich dravých vtákov bola odhadnutá na základe kolmých vzdialeností vtákov od transektových línií. Pozorovaných bolo desať druhov (9 dravých vtákov), ale len dva druhy, myšiak lesný (*Buteo buteo*) a sokol myšiar (*Falco tinnunculus*), boli zaznamenané v dostatočnej početnosti, aby bolo možné spoľahlivo odhadnúť ich hustotu. Rozsiahle ryžové polia v severovýchodnej časti študovanej oblasti podporovali vysokú hustotu myšiakov lesných, s odhadmi v rozmedzí 1 až 2 jedincov na km². Sokol myšiar vykazoval širšiu toleranciu biotopov a zdá sa menej závislý od špecifickej poľnohospodárskej krajiny, hoci sa vyskytoval v nižšej hustote (~0,5 jedincov na km²). Odhadovaná zimujúca populácia myšiaka lesného v nížinných poľnohospodárskych oblastiach regiónu Piemonte, ktoré pokrývajú približne 5700 km², bola o niečo vyššia ako populácia zaznamenaná pred 20 rokmi a pohybovala sa v rozmedzí 4000 až 5000 jedincov. V prípade sokola myšiara bola odhadovaná zimujúca populácia v tej istej oblasti približne 2500 jedincov (1800 – 3500). Zimujúce populácie oboch druhov v celom regióne však boli určite oveľa väčšie, pretože oba druhy sa v zime vyskytujú v kopcovitých a horských oblastiach. Celkovo výsledky zdôraznili význam ryžových polí pre zimovanie myšiakov lesných, naznačili stabilitu v spoločenstve dravých vtákov a podporili širšie uplatňovanie metód vzdialenostného vzorkovania pre efektívne veľkoplánne prieskumy vtáctva.

Key words: road counts, distance sampling method, density, common buzzard, common kestrel

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Introduction

Road surveys by car while driving at slow speed are among the most common methods to count diurnal raptors, especially in open habitats and in winter seasons, as noted from the first papers of Nice (1934) and Leopold (1942) up to present days (Fuller & Mosher 1987, McClure et al. 2021). From these counts, we obtain an index of the relative abundance usually expressed as birds per kilometre, but not an estimate of density (birds per unit area).

Comparisons of these indices of abundance among areas, times, and/or different species could be made only assuming similar sighting probabilities, although assumptions rarely meet for species of various sizes and detectability or in habitats with different vegetation cover (Burnham et al. 1981); moreover detection probability could even change between years in the same habitat/area (Andersen et al. 1985).

The road surveys also show a considerable variation in methodology, including vehicle speed, times of day and year, number of observers, and transect width, so it would be recommended that road count practitioners record information that affects the detectability of raptors, thus enabling detection corrected estimates allowing reliable comparisons within and among monitoring programs (McClure et al. 2021).

Comparisons of density estimates avoid these problems, but generally require labour-intensive methods, usually applicable only to limited areas and territorial birds, such as territory mapping. Another way to obtain density estimates of wintering raptors over large areas may be provided by the “distance sampling method” described in depth by the monographs of Buckland et al. (1993, 2015). Distance sampling consists of line transects with the registration of the perpendicular distance from the line of the objects of interest (Burnham et al. 1981) or point counts measuring the radial distance from the observer to the objects (Reynolds et al. 1980, Buckland 1987).

Even if the underlying theory is the same, and point counts are conceptually like line transects for which the lines have zero length, points are less robust to monitor

scarce species than are transects, because some time is spent moving from one point to another point instead of counting birds along the complete transect. The variance of the count is also greater with points than with transects because of mathematical reasons (Buckland et al. 1993).

Despite their potential usefulness, the above methods were rarely applied until now to raptor density estimation (McClure et al. 2021), especially in Europe (but see Boano & Toffoli 2002, Nikolov et al. 2006, Baltag et al. 2013, Steven et al. 2019).

As previously (Boano & Toffoli 2002), we decided to use the line transect method and investigate the same area of the western Po plain after twenty years, with the scope to show eventual changes in the guild of wintering raptors and of the densities of the commonest species.

Materials and Methods

Study area

The study area encompasses two distinct zones within the Po River plain, corresponding to the geographically separated western and north-eastern sectors, which differ in dominant land use, maize cultivation in the west and rice fields in the northeast. The western plain includes relatively high habitat heterogeneity, with humid meadows, small fallow fields, scattered poplar plantations, and remnants of natural woodlots, largely due to poorer soil quality and lower agricultural productivity (IPLA 1982). In our previous study (Boano & Toffoli 2002), these heterogeneous zones were treated as separate habitats. However, over the past two decades, such features declined markedly in both extent and continuity. Humid meadows decreased by approximately 50%, and poplar plantations by over 90% in surface area (www.sistemapiemonte.it). For the current analysis, these areas have been merged with the rest of the western plains, just as we have merged the south-eastern plains, where wheat is the predominant crop, with the western area, as the two share similar land-use characteristics. Maize cultivation is also common in this zone, particularly near the Po River.

The north-eastern sector is mainly occupied by rice monoculture, and the heathlands of the northernmost area,

once quite extensive and considered a separate habitat in the previous work (Boano & Toffoli 2002), have been greatly fragmented and largely converted into rice fields. Counts were carried out over two consecutive winters: from 8 January to 25 February 2021 (winter 2020/2021), and from 3 December 2021 to 19 February 2022 (winter 2021/2022).

The average minimum temperatures in January and February 2021 (-1.3°C and +1.8°C, respectively) were higher than those recorded in the same months of 2022 (-2.5°C and -1.1°C) (www.arpa.piemonte.it). Sampling was stratified (Sutherland 1996) by winter and prevailing rural landscape structure.

Two macro-habitats were defined as follows:

Mixed crops: areas characterised by intensive agriculture, predominantly maize, but also wheat, meadows, and soybeans. This habitat covers most of the western and south-eastern plains, with an estimated area of 4,200 km².

Rice fields: This area, located North of the Po River and between the Dora Riparia and the Ticino rivers, is dominated by intensively managed, almost treeless rice fields, interspersed only occasionally with isolated poplars or oaks, and includes a single 4 km² wooded patch. In the northernmost portion, more recent rice field expansion has occurred at the expense of the heathland of ancient pastoral origin. The total surface of this habitat is approximately 1,500 km².

Based on our previous work and the considerations of Buckland et al. (1993), we selected the linear transect method, taking note of the transect length, species observed and perpendicular distances between the transect line and each observed bird. To obtain unbiased and representative estimates of densities realised by raptors in the whole area, according to Buckland et al. (1993, 2015), it is necessary to respect some conditions, in particular: the detection probability of the birds on the transect line should be 1; perpendicular distances of the observed birds from the transect are correctly estimated; the transect is allocated randomly with respect to the distribution of birds.

The first is the most crucial assumption of the method: the lack of detection of some individuals just on (or very nearby) the transect line irremediably biases the results; on the contrary, the method explicitly allows some animals to go undetected away from the transect line. In practice, it is necessary to ascertain that no birds fly away from the transect line undetected. This condition is not very difficult to obtain in open country with medium to big raptors like common buzzard (*Buteo buteo*), but may be a common cause of problems with little or more

elusive species flying away well before being seen from the approximating observer, like Eurasian sparrowhawk (*Accipiter nisus*) or merlin (*Falco columbarius*).

All the authors alternated between the roles of observer and driver and the accuracy of the observations and measures was improved with a slow speed (15 to 40 km/h) and using a rangefinder like binoculars LEICA Geovid 7 X 42 BDA (precision of ±1 m; range 25–1000 m) and LEICA Rangemaster 1200 that estimate the distances with a laser telemeter (precision of ±1 m; range 10–1200 m). The distances of birds under 10 m were paced or visually estimated. Birds flying away from the line due to the approaching car were measured at the distance they were first seen. A few birds flying independently from our approach were recorded when they came abeam of the observer's car. All the birds observed were counted without truncation distance, and, due to the open habitat, we saw birds up to 650 and, exceptionally, up to 850 m. We carried out the counts mainly by covering secondary and dirt roads and avoiding main roads, on days of low work traffic.

The observation effort was 416 km in the first winter and 546 km in the second, subdivided into transects of variable length according to routes and macro-habitats, averaging about 10 km each, and are reported in the map (Fig. 1). We included in transects the little country towns under 2 km of crossing due their relatively high frequencies in the area.

During the observation period, the birds were wintering, and there was no noticeable movement. Raptors, even in winter, are territorial, so we did not observe clusters of birds, and all the observations were independent of each other.

We counted mainly from 10:00 to 15:00, as in winter the daytime in our region is relatively short, and at 16:00–16:30 the night is descending; and in the morning, fog conditions frequently occur. In each stratum, we made observations in the same hourly period.

Analysis of densities with the program DISTANCE was limited to the species with more than 60 observations, thus possible only for the common buzzard and the common kestrel (*Falco tinnunculus*). Data were right-truncated at 480 m to reduce the effect of data having an extended tail, especially for common buzzards, so we excluded 5% of common buzzard and 2.5% of common kestrel observations.

We adopted three analytical approaches based on the principles of Distance Sampling (Buckland et al. 1993): (a) **Conventional Distance Sampling (CDS)** with a *pooled detection function*, assuming identical detection

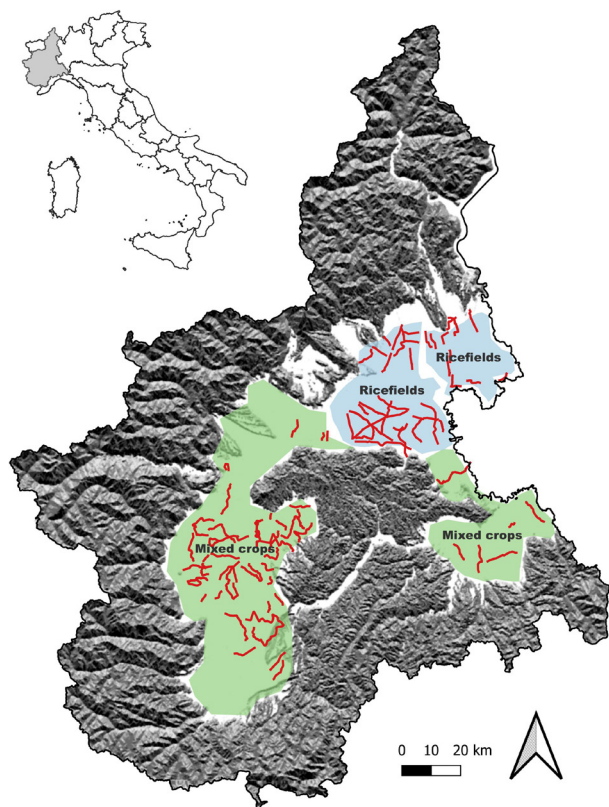


Fig. 1. The study area in the western Po Plain in Italy with transects driven/sampled during the two study winters (red lines) and the two studied macro-habitats: mixed crops (green) and ricefields (azure).
Obr. 1. Sledovaná oblasť v západnej časti Pádskej nížiny v Taliansku s transektmi, ktoré boli prejdené/vzorkované počas dvoch študovaných zím (červené čiary), a dva študované makrohabitaty: zmiešané plodiny (zelená farba) a ryžové polia (azurová farba).

probability across all surveys; (b) **CDS with stratified detection functions**, where each stratum corresponded to one of the two macro-habitats (mixed crops and rice fields) in each winter season; (c) **Multiple-Covariate Distance Sampling (MCDS)**, incorporating covariates expected to influence detectability: habitat stratum (HAB), month of observation (MTH), and observer identity (OBS).

Detection functions were fitted using both the half-normal and the hazard-rate key functions, with cosine, simple polynomial, or Hermite polynomial adjustment terms. The most parsimonious model was selected based on Akaike's Information Criterion (AIC (Burnham & Anderson 1992, Laake et al. 1993).

To compare density estimates among macro-habitats and years, we used the program CONTRAST (Hines &

Sauer 1989), a chi-square analysis with multiple comparisons, which enables statistical comparison of multiple parameter estimates, provided their associated variances. The null hypothesis is that there is no difference among the tested estimates.

Results

We counted 504 raptors plus 11 great grey shrikes (*Lanius excubitor*) subdivided by species, seasons and areas as shown in Table 1. Common buzzards, common kestrels, peregrine falcons (*Falco peregrinus*) and great grey shrikes were observed mainly when perching or waiting for food. Red kites (*Milvus milvus*), hen harriers (*Circus cyaneus*), marsh harriers (*Circus aeruginosus*), Eurasian sparrowhawks, northern goshawks (*Astur gentilis*), and merlins were usually spotted in flight. Excluding the common buzzard and common kestrel, the only two species generating a sufficient number of observations to allow an analysis of density, the indices of abundance (ind./km) of all other species was generally low, about one per 100 km for peregrine falcon, red kite, sparrowhawk, and great grey shrike, or even less (Table 1).

Common buzzard density

All the tested models supported half-normal key functions with cosine adjustment terms (Table 2). According to AIC, the best - supported model was MCDS with detection function differentiated across strata (habitats and years), and observers as factor covariate. We used the estimates from this unpooled analysis for the subsequent generation of density estimates (Table 3).

The DISTANCE analysis of transects conducted during the first winter showed a relatively lower density than the second winter (Table 3). We observed a marked difference between macro-habitats during both winters, with densities in rice fields about two to four times greater than in mixed crops. The selected model gave an effective strip half-width, the distance from the transect line at which as many individuals are overlooked as recorded, of 210 m and the average probability of detection was estimated to be 0.44 (CV = 4.11%).

A contrast analysis (Hines and Sauer, 1989) rejected the null hypothesis of no differences in the density estimates among the four strata ($\chi^2 = 55.874$, $df = 3$, $P < 0.001$). Similar results were obtained when comparing densities between the two macro-habitats, by pooling data across different years ($\chi^2 = 50.864$, $df = 1$, $P < 0.001$), or during winters, by pooling densities within each macro-habitat ($\chi^2 = 10.536$, $df = 1$, $P = 0.001$).

Tab.1. Total number of raptors and shrikes (n) observed in the two winter study seasons, subdivided into the two macro-habitats, with the sampling effort for each winter and habitat reported as the length of the transects in kilometres (“Km”).

Tab.1. Celkový počet dravých vtákov a strakošov (n) pozorovaných v dvoch zimných sezónach štúdie, rozdelených do dvoch makrohabitatov, s úsilím vzorkovania pre každú zimu a habitatom uvedeným ako dĺžka transektov v kilometroch („Km“).

Species	Winter 2020/2021						Winter 2021/2022						Total	
	Mixed crops		Rice fields		Total		Mixed crops		Rice fields		Total		Total	
	Km 262		Km 154		Km 416		Km 372		Km 164		Km 546		Km 962	
	n	n/km	n	n/km	n	n/km	n	n/km	n	n/km	n	n/km	n	n/km
Common buzzard	64	0.24	77	0.5	141	0.34	71	0.19	162	0.99	233	0.43	374	0.39
Common kestrel	28	0.11	16	0.1	44	0.11	23	0.06	15	0.09	38	0.07	82	0.09
Eurasian sparrowhawk	3	0.01	0	-	3	0.01	8	0.02	3	0.02	11	0.02	14	0.01
Peregrine falcon	3	0.01	2	0.01	5	0.01	4	0.01	3	0.02	7	0.01	12	0.01
Red kite	1	0	6	0.04	7	0.02	1	0	2	0.01	3	0.01	10	0.01
Marsh harrier	0	-	4	0.03	4	0.01	0	-	3	0.02	3	0.01	7	0.01
Hen harrier	0	-	3	0.02	3	0.01	0	-	0	-	0	-	3	0
Northern goshawk	0	-	1	0.01	1	0	0	-	0	-	0	-	1	0
Merlin	1	0	0	-	1	0	0	-	0	-	0	-	1	0
Great grey shrike	3	0.01	1	0.01	4	0.01	7	0.02	0	-	7	0.01	11	0.01

Common buzzard density was variable over the winters and macro-habitats; however, the values obtained in this study are quite comparable to those obtained during the previous survey of the winter 1999/2000 (Fig. 2). Finally, from our density estimates, we can get for the entire sampled area 4,009 (2,965–5,422) birds in the winter 2020/2021 (overall mean 0.70 individuals per km²) and 5,221 (4,061–6,719) in the winter 2021/2022 (mean = 0.92).

Common kestrel density

Despite being the second most abundant species, the common kestrel had much lower encounter rates than the common buzzard, and we were unable to collect a

sufficient number of observations (i.e. more than sixty) for each different strata (macro-habitats and winters). As for the common buzzard, all the models supported half-normal key functions with cosine adjustment terms. The analyses showed no difference in detection rate by strata, and the model selection procedure indicated the pooled CDS model as the best (Table 4). All models with covariates were discarded according to the AIC. So we calculated the densities in the two habitats and winters from this model, and obtained very similar densities in each stratum (Table 5). This model gave an effective strip half-width of 97 m, and the average probability of detection was estimated to be 0.20, Coefficient of Variation = 10.24%.

Tab. 2. Common buzzard: model-selection results. Models are sorted by AIC (Akaike’s Information Criterion). Model: CDS = conventional distance sampling, MCDS = multiple-covariates distance sampling; Covariates: HAB = Habitats, MTH = months, OBS = observers. N par. = number of parameters; ΔAIC = difference in AIC between the candidate model and the model with the lowest AIC.

Tab. 2. Myšiak lesný: výsledky výberu modelu. Modely sú zoradené podľa AIC (Akaikeho informačného kritéria). Model: CDS = konvenčné vzorkovanie vzdialenosti, MCDS = vzdialenostné vzorkovanie s kovariátmi; Kovariáty: HAB = biotopy, MTH = mesiace, OBS = pozorovatelia. N par. = počet parametrov; ΔAIC = rozdiel v AIC medzi kandidátskym modelom a modelom s najnižším AIC.

Model	Covariates	N Par.	AIC	ΔAIC
MCDS	OBS	4	1224.52	0
CDS (stratified detection function)		6	1226.1	1.57
MCDS	HAB+OBS	5	1226.11	1.59
MCDS	OSS+MTH	6	1227.86	3.33
MCDS	HAB+OBS+MTH	7	1229.33	4.8
CDS (pooled detection function)		2	1230.84	6.32
MCDS	HAB	2	1237.44	12.92
MCDS	HAB + MTH	4	1238.56	14.04
MCDS	MTH	3	1239.18	14.66

Tab. 3. Common buzzard: summary of the results of the DISTANCE analysis according to the model MCDS with covariate OBS. k = samples (transects); L = total transects length; n = number of individuals counted; n/L = encounter rate; SE = standard error; CV% = Coefficient of Variation %; D = Density estimates (expressed as individuals per km²); 95% LCL = 95% lower coefficient limit; 95%; UCL = 95% upper coefficient limit.

Tab. 3. Myšiak lesný: zhrnutie výsledkov analýzy DISTANCE podľa modelu MCDS s kovariátom OBS. k = vzorky (transekt); L = celková dĺžka transektov; n = počet spočítaných jedincov; n/L = miera výskytu; SE = štandardná chyba; CV% = koeficient variácie %; D = odhad hustoty (vyjadrený ako počet jedincov na km²); 95 % LCL = 95 % dolná hranica koeficientu; 95 %; UCL = 95 % horná hranica koeficientu.

Winter	Macro habitat	k	L (km)	n	n/L	SE (n/L)	%CV (n/L)	D (ind./km ²)	SE (D)	CV% (D)	95% LCL (D)	95% UCL (D)
2020/21	mixed crops	31	262	63	0.24	0.03	13.69	0.57	0.08	14.29	0.43	0.77
2020/21	rice fields	27	154	69	0.45	0.07	15.31	1.07	0.17	15.85	0.77	1.47
2021/22	mixed crops	36	372	71	0.19	0.03	14	0.45	0.07	14.59	0.34	0.61
2021/22	rice fields	18	164	152	0.93	0.1	10.26	2.21	0.24	11.05	1.76	2.77

Moreover, the contrast analysis (Hines & Sauer 1989) among the four density estimates did not show any statistical differences ($\chi^2 = 2.722$, $df = 3$, $P = 0.436$). For this reason, we used the global estimate of 0.44 (SE = 0.08) birds for km² for the entire sampled area to estimate a wintering population of about 2,508 (95% CIs = 1,767–3,534).

Discussion

The raptor species composition was found to be similar to the result of the survey made 20 years ago with a similar sampling effort (Boano & Toffoli 2002). The biggest difference was that we found quite a good number of marsh harriers, due to a larger sample of transect routes in the rice field area and probably an increase in winter visitors. The species experienced a moderate increase in wintering individuals in Italy (Zenatello et al. 2014). All the other recorded raptor

species showed an encounter rate that was not substantially different and generally very low. The only two species with a number of records that allowed the possibility of calculating the densities were the common buzzards and the common kestrels. This pattern is common over a wide area in European agroecosystems (Ševčík 1995, Mülner 2000, Nemček 2013).

Also, for common buzzard and common kestrel, our estimates should refer to the limited areas along the transect roads, but we think that the estimates could be considered good approximations of the densities typical of the whole investigated area. The agricultural landscape of the region shows great homogeneity.

Moreover, the selected transects were mainly secondary roads, irregularly crossing the entire area and representing a common feature of the territory, and the effective strip half-width was very large.

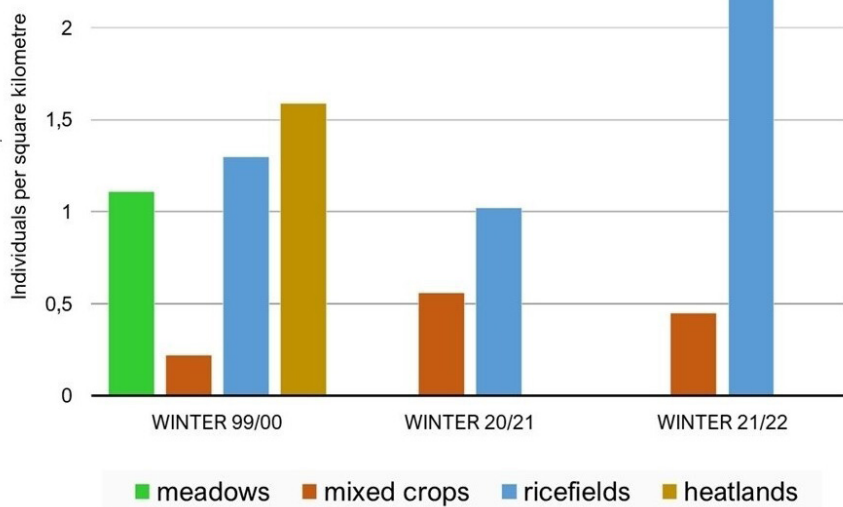


Fig 2. Common buzzard density estimate comparisons among the two studied macro-habitats and the two study winters, including the data for 1999/2000 taken from Boano & Toffoli (2002). For the winters 2020/2021 and 2021/2022, the surfaces of the remaining "meadows" and "heatlands" were respectively included in the "mixed crops" and in the "rice fields" (see study area paragraph).

Ob. 2. Porovnanie odhadov hustoty myšiaka lesného medzi dvoma študovanými makrohabitatmi a dvoma sledovanými zimami, vrátane údajov za rok 1999/2000 prevzatých z Boano & Toffoli (2002). Pre zimy 2020/2021 a 2021/2022 boli plochy zostávajúcich „lúk“ a „vresovísk“ zahrnuté do „zmiešaných plodín“ a „ryžových poľí“ (pozri Study area).

Tab. 4. Common kestrel: model-selection results. Models are sorted by AIC (Akaike's Information Criterion). Model: CDS = conventional distance sampling, MCDS = multiple-covariates distance sampling; Covariates: HAB = macro-habitats, MTH = months, OBS = observers. N par. = number of parameters; Δ AIC = difference in AIC between the candidate model and the model with the lowest AIC.

Tab. 4. Sokol myšiar: výsledky výberu modelu. Modely sú zoradené podľa AIC (Akaikeho informačného kritéria). Model: CDS = konvenčné vzorkovanie vzdialenosti, MCDS = vzorkovanie vzdialenosti s viacerými kovariátmi; Kovariáty: HAB = makrohabitat, MTH = mesiace, OBS = pozorovatelia. N par. = počet parametrov; Δ AIC = rozdiel v AIC medzi kandidátskym modelom a modelom s najnižším AIC.

Model	Covariates	N Par.	AIC	Δ AIC
CDS (pooled detection function)		4	216.49	0
CDS (stratified detection function)		5	219.55	3.06
MCDS	OBS+MTH	6	222.9	6.41
MCDS	HAB+OSS+MTH	7	224.71	8.22
MCDS	OBS	4	226.21	9.72
MCDS	HAB+MTH	4	227.14	10.65
MCDS	HAB+OBS	5	228.05	11.56
MCDS	HAB	2	228.85	12.36
MCDS	MHT	3	228.95	12.46

The data confirmed the importance of the region's rice fields at a national level for the wintering common buzzards: the encounter rate (birds/km) was well over that of other Italian regions and of many Mediterranean countries (Sarà 1996, Boano & Toffoli 2002).

The lower temperature in January and February 2022 could account for the higher density of common buzzards observed in the second winter in the study area, particularly in the rice fields, while they remained more stable in mixed crops. Buzzard abundance in winter is often associated with lower temperatures (Baltag et al. 2013) and/or the availability of prey, which in turn is influenced by climate and agricultural practices (Laber & Zuna-Kratky 2005). Variation in prey abundance likely also played a significant role, though recent studies on rodent density and raptor prey in the area are lacking. The only existing information comes from stomach content analysis of common buzzards caught in our study area in January (Moltoni 1937), which revealed that the

commonest prey were rodents (*Arvicola*, *Micromys*), reptiles (*Natrix*) and frogs (*Rana*).

Therefore, the current common buzzard's overall wintering population of the investigated area appeared relatively stable, though a bit higher, in comparison with that of 3,180 (2,690–3,760) obtained on 4,700 km² (i.e. mean = 0.68 inds./km²) of the same area without the south-eastern plains in the winter 1999/2000 (Boano & Toffoli 2002).

The density estimates were still lower than those obtained with intensive searches or mapping methods in some Central European countries, as Germany and France, mainly reported in general handbooks (Glutz & Bauer 1980 and references therein, Yeatman-Berthelot 1991, Wuczyński 2003), and not easily comparable with ours. However, considering only the estimates obtained with comparable distance sampling methods, the common buzzard densities found in our study area score among the highest obtained in Europe (Boano & Toffoli 2002,

Tab. 5. Common kestrel: summary of the results of the DISTANCE analysis with the CDS Model Half Normal+cosine, detection global, data right truncated at 480 m. k = samples (transects); L = total transects length; n = number of individuals counted; n/L = encounter rate; SE = standard error; CV% = Coefficient of Variation %; D = Density estimates (expressed as individuals per km²); 95% LCL = 95% lower coefficient limit; 95% UCL = 95% upper coefficient limit.

Tab. 5. Sokol myšiar: zhrnutie výsledkov analýzy DISTANCE s modelom CDS Half Normal+cosine, globálna detekcia, údaje skrátené na 480 m. k = vzorky (transekty); L = celková dĺžka transektov; n = počet spočítaných jedincov; n/L = miera výskytu; SE = štandardná chyba; CV% = koeficient variácie %; D = odhad hustoty (vyjadrený ako počet jedincov na km²); 95 % LCL = 95 % dolná hranica koeficientu; 95 % UCL = 95 % horná hranica koeficientu.

Winter	Macro habitat	k	L (km)	n	n/L	SE (n/L)	%CV (n/L)	D (ind./km ²)	SE (D)	CV% (D)	95% LCL (D)	95% UCL (D)
2020/21	mixed crops	31	262	28	0.11	0.03	26.52	0.55	0.16	28.43	0.31	0.97
2020/21	rice fields	27	154	15	0.1	0.03	27.31	0.5	0.15	29.16	0.28	0.9
2021/22	mixed crops	36	372	23	0.06	0.01	20.58	0.32	0.07	22.99	0.2	0.5
2021/22	rice fields	18	164	14	0.09	0.03	29.59	0.44	0.14	31.31	0.23	0.83
Pooled	pooled	112	952	80	0.08	0.01	13.21	0.44	0.08	17.68	0.31	0.63

Nikolov et al. 2006, Baltag et al. 2013, Panuccio et al. 2019), except for those found in some winters in middle Austria, reaching 3–4 inds./km² (Laber & Zuna-Kratky 2005).

Our results confirmed that common kestrel detectability declines more rapidly than that of common buzzards with increasing distance (Pannuccio et al., 2019), as indicated by the lower effective strip half-width for common kestrels (97 m) compared to buzzards (210 m). This difference likely accounts for the absence of observer effects on common kestrel detectability. Nonetheless, the distance sampling method, which accounts for varying detectability, still indicates a lower abundance of common kestrels than common buzzards, even if the first species is apparently more evenly distributed across winter habitats. Also during the breeding season, common kestrels have been shown to be more widespread and better adapted to a larger variety of landscape types (Butet et al. 2022). Our findings indicated that this also remains the case in winter, despite the higher abundance of common buzzards.

The lower detectability and density of the common kestrel made it more challenging to obtain an adequate sample for distance analysis with this level of field effort. Therefore, it is unsurprising that our winter density estimate is the first for the study region, and one of the few for Europe based on methods that consider the detection probability (Burnham et al. 1981). For comparison, the average value of 0.44 inds./km² (\pm 0.08 SE) found in Piedmont seems to be intermediate between the values found by Panuccio et al. (2019) in Sicily (0.75 ± 0.10 SE) and in Crete (0.26 ± 0.04 SE).

Finally we emphasize that the line transect method, which is unfortunately not still widespread in raptor-surveys in Europe, if correctly applied in open agricultural habitat, can generate, with a moderate effort, good results for the most familiar and widespread species, like the common buzzard and common kestrel, and should be used for future raptor surveys to provide more rigorous comparisons of density and abundance estimates over time and large areas. To obtain an acceptable sample to calculate the density of other scarcer wintering raptors, an effort 4–5 times greater would be required. Larger samples could allow more detailed environmental analyses even for the commonest species. Further, gathering precise information on the abundance of available prey species in the study area would be helpful.

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First observation of the Amur falcon (*Falco amurensis*) in Algeria

Prvé pozorovanie sokola amurského (*Falco amurensis*) v Alžírsku

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Abstract: We report the first record of the Amur falcon (*Falco amurensis*) in Algeria and throughout North Africa, based on a single individual observed and photographed on 15 July 2025 and again on 3 August 2025 in the Illizi region, southeastern Algeria. The bird was documented using a Nikon Coolpix P900 camera in an open Saharan habitat characterised by sparse desert vegetation. This observation represents a westward extension of the known distribution of the species into the central Sahara. It constitutes a notable case of vagrancy well beyond its typical migratory corridor between eastern Asia and southern Africa. This finding underscores the species' potential for long-distance dispersal and highlights the importance of continued monitoring for rare migratory birds in arid zones of Algeria or throughout North Africa.

Abstrakt: Uvádzame prvý záznam sokola amurského (*Falco amurensis*) v Alžírsku a v celej severnej Afrike. Jeden jedinec bol pozorovaný a odfotografovaný 15. júla 2025 a opäť 3. augusta 2025 v regióne Illizi v juhovýchodnom Alžírsku. Vták bol zdokumentovaný pomocou fotoaparátu Nikon Coolpix P900 v otvorenom saharskom biotope charakterizovanom riedkou púštnou vegetáciou. Toto pozorovanie predstavuje rozšírenie známeho výskytu druhu na západ do centrálnej Sahary. Ide o pozoruhodný prípad výskytu mimo typického migračného koridoru medzi východnou Áziou a južnou Afrikou. Tento nález podčiarkuje potenciál druhu na šírenie na veľké vzdialenosti a zdôrazňuje dôležitosť pokračujúceho monitorovania vzácných sťahovavých vtákov v suchých oblastiach Alžírsku alebo v celej severnej Afrike.

Key words: Falconidae, North Africa, Sahara, vagrancy, migratory birds, long-distance dispersal, raptors

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Introduction

The term birds of prey has traditionally been applied to a distinct assemblage of avian predators, comprising, for instance, kites, vultures, hawks, eagles, and falcons, despite the widespread occurrence of predatory behaviour among numerous avian taxa (Ferguson-Lees & Christie 2001). These are now more accurately referred to as 'raptors', specifically 'diurnal raptors' (Wink 2007). Taxonomically, diurnal raptors are grouped into five families: Accipitridae, Pandionidae, Sagittariidae, Falconidae, and Cathartidae, and are generally classified within the order Falconiformes (Del Hoyo et al. 1994).

The family Falconidae comprises diurnal raptors, characterised by sharp talons, hooked beaks, and agile

flight. It is currently divided into three subfamilies: Herpetotherinae, Polyborinae, and Falconinae, encompassing 11 genera and 64 recognised species. Notably, approximately 72% of these species are classified within the subfamily Falconinae, which includes the pygmy falcons, falconets, and true falcons (Ferguson-Lees & Christie 2001, Fuchs et al. 2015, Leonardi 2020; Gill et al. 2025).

The Amur falcon (*Falco amurensis*) is a small migratory falcon that breeds across the eastern Palearctic, including southeastern Siberia, central and eastern Mongolia, northeastern China, and the Korean Peninsula (White et al. 1994, Burner et al. 2019, Gill et al. 2025). It migrates to overwinter in southeastern Africa and parts of southern Asia (Borrow & Demey 2014).

In Algeria, the order Falconiformes is represented by a single family, Falconidae, and only one subfamily, Falconinae. This subfamily comprises 11 species (Isenmann & Moali 2000, Ledant et al. 1981). The present note reports the first confirmed record of the Amur falcon in Algeria or throughout North Africa.

Material and methods

The study was conducted in the province of Illizi, situated in the extreme southeast of Algeria, approximately 1,758 km from the capital, Algiers. Illizi lies between latitudes 26° 30' 29" N and longitudes 8° 28' 59" E, covering a total area of 198,433 km² (Fig. 1). The province shares borders with Tunisia to the northeast, Libya to the east, and by the Algerian provinces Djanet to the south, In Salah to the west, and Ouargla to the north. It forms part of Tassili n'Ajjer, which includes the Tassili n'Ajjer National Park, a UNESCO World Heritage Site noted for its sandstone formations and prehistoric rock art (Coulson & Campbell 2010). Recent studies have reported notable faunal records in this area, including, for instance, the African crane (*Crecopsis egregia*) (Bederrar et al. 2023), the bateleur (*Terathopius ecaudatus*) (Gueroui et al. 2024), and data on new occurrences of mammals (Irzagh et al. 2020). A bird count was carried out on 15 July 2025 to the north of the town of Illizi (26° 32' 03.7" N, 8° 28' 25.7" E). The survey lasted two and a half hours, from 17:30

to 20:00, and followed a transect-based counting method. Birds were identified and recorded visually in the field, with the assistance of a professional bird guide. Photographic documentation was obtained using a Nikon Coolpix P900 digital camera, featuring an 83× optical zoom (equivalent to a 2000 mm focal length).

Results

The individual falcon was initially identified in the field as a red-footed falcon (*Falco vespertinus*). However, closer examination of the photographs has cast doubt on this identification. The bird was similar in size to other members of the genus *Falco* and was first photographed on 15 July at 18:35, perched on a tree branch of *Calotropis procera* (Fig. 2 and 3), under natural evening light, which provided adequate conditions for detailed observation and photographic documentation. It remained stationary and in view for several minutes before taking flight and disappearing behind a nearby ridge. A second sighting, likely of the same individual, occurred at the exact location on 3 August 2025 (Fig. 4).

Based on plumage characteristics visible in the photographs, the observed individual was identified as a male in post-juvenile moult. It was uniformly grey-brown above, with buff- or rufous-edged feathers on the back and wings, a hint of a pale collar, and reduced contrast on the sides of the head. The underparts were cream-

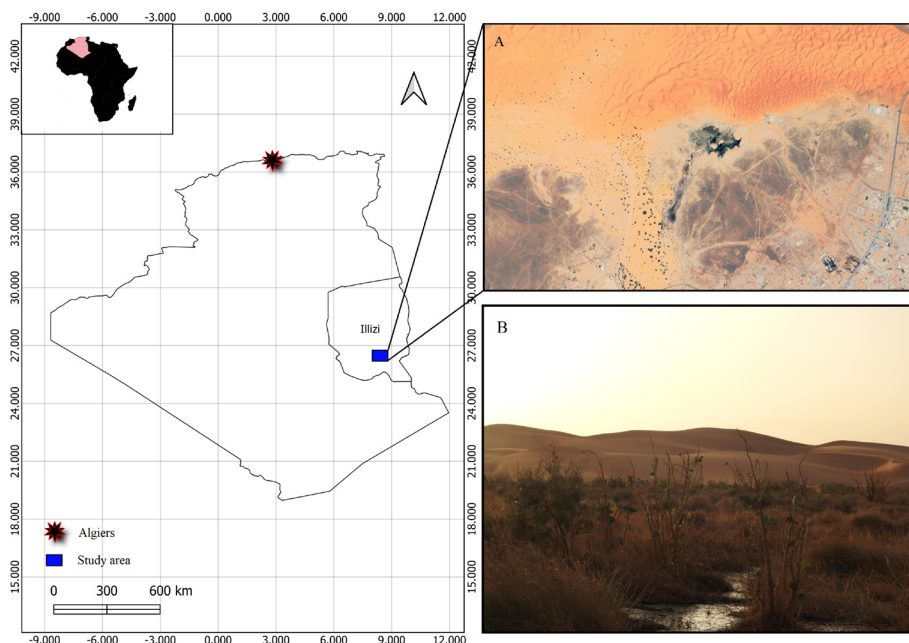


Fig. 1. Map of the study site in Algeria - Illizi region (A) and view of the observation site (B).
Obr. 1. Mapa študovanej lokality v Alžírsku - región Illizi (A) a pohľad na miesto pozorovania (B).



Fig. 2. Amur falcon (*Falco amurensis*) observed in Illizi province, representing Algeria's first record of this species.

Obr. 2. Sokol amurský (*Falco amurensis*) pozorovaný v provincii Illizi, reprezentujúci prvý záznam tohto druhu v Alžírsku.



Fig. 3. Amur falcon (*Falco amurensis*) perched on a *Calotropis procera* in southern Algeria.

Obr. 3. Sokol amurský (*Falco amurensis*) sediaci na *Calotropis procera* v južnom Alžírsku.

coloured with distinct longitudinal streaking, the tail appeared greyer, and the bare parts, including legs and cere, were yellow (Ferguson-Lees & Christie 2001).

Discussion

Within the Western Palearctic, vagrant Amur falcon individuals have been documented in several countries, including Italy (Corso & Dennis 1998), Iran (Lantsheer et al. 2009), Iraq (Salim et al. 2024), Sweden and England (Hudson et al. 2010), and the Faroe Islands (Birdingfaroes 2015). Beyond this region, the species has also been reported as an exceptional vagrant on St. Helena Island in the South Atlantic Ocean (Rowlands et al. 1998) and on islands in the western Pacific, such as Saipan and Sarigan in the Mariana archipelago (Stinson et al. 1997).

Our observation is the first confirmed record of the Amur falcon in Algeria and throughout North Africa, adding a new species to the regional *Falconidae* assemblage (Isenmann & Moali 2000, Isenmann et al. 2005). The plumage characteristics indicate that the observed individual was a male in post-juvenile moult, suggesting that its presence in the region most likely corresponds to the first spring migration, a period during which such records are rarely documented. In this case, the possible explanation might be that the observed individual got astray during its first autumn migration, or

during the spring migration on its way back to breeding grounds. These observations overall support the notion that some raptors may deviate from their usual migration flyways due to weather or navigational disturbances,



Fig. 4. Amur falcon (*Falco amurensis*) observed on 3 August 2025 in Illizi province in southern Algeria.

Obr. 4. Sokol amurský (*Falco amurensis*) pozorovaný 3. augusta 2025 v provincii Illizi v južnom Alžírsku.

appearing as vagrants in novel areas. Such occurrences, also reported in studies of Neotropical raptor migration, may result in mortality, successful reorientation, or, in rare cases, settlement and breeding in isolation from the parental population (Bildstein 2004).

During our observational study, we further recorded the presence of several other raptor species, including the common kestrel (*Falco tinnunculus*), the red-footed falcon, the lanner falcon (*Falco biarmicus*), and the lesser kestrel (*Falco naumanni*). In addition, an osprey (*Pandion haliaetus*) was also observed. These observations underscore the significance of the region as a key corridor within the migratory route of raptors between Europe and Africa.

Over the past decade, the avifauna of the Algerian Sahara, which covers nearly 80% of the country, has been enriched by several Afrotropical species, including the Dunn's lark (*Eremalauda dunnii*) (Harzallah et al. 2021); African crane (Bederrar et al. 2023); the cricket warbler (*Spiloptila clamans*), the blue-naped mousebird (*Urocolius macrourus*), the northern grey-headed sparrow (*Passer griseus*) and the chestnut-bellied starling (*Lamprolornis pulcher*) (Boulaouad et al. 2024a, 2024b); the bateleur (Gueroi et al. 2024); and the yellow-billed egret (*Ardea brachyrhyncha*) (Kattenhøj & Dinets 2024). These records point to a northward range expansion and highlight the biogeographical importance of the central Algerian Sahara. This context is directly relevant to our Amur falcon observations, which further illustrate how ongoing environmental changes and intensified field monitoring reshape the distribution of Afrotropical birds in the study region.

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