ORNIS HUNGARICA

ISSN 1215-1610

JOURNAL OF THE BIRDLIFE HUNGARY

Ornis Hungarica 2023. 31(1): 1–23.
DOI: 10.2478/orhu-2023-0001

Bearded Reedling *(Panurus biarmicus)*: the biology of a remarkable bird – a review of the recent literature

Ádám Z. Lendvai

Received: April 12, 2022 – Revised: May 07, 2023 – Accepted: May 09, 2023

Lendvai, Á. Z. 2022. Bearded Reedling *(Panurus biarmicus)*: the biology of a remarkable bird – a review of the recent literature. – Ornis Hungarica 31(1): 1–23. DOI: 10.2478/orhu-2023-0001

Abstract The Bearded Reedling *Panurus biarmicus* is a frequent, yet relatively little-known passerine bird found in wetlands across Eurasia. The species is difficult to study because of its elusive nature and the challenging access to its habitat: old, particularly dense reed patches standing in water. However, a detailed body of knowledge of the species' natural history, morphology, and behaviour has been gathered over the years, providing insight into the adaptations this unusual bird uses to survive and even thrive under favourable conditions. In 2023, BirdLife Hungary named the Bearded Reedling as the 'bird of the year'. In light of this notable designation, this article provides an overview of research advances on some of the unique characteristics of the Bearded Reedling, focusing on the factors that affect their population dynamics and potential conservation management strategies to protect the species.

Keywords: Bearded Reedling, *Panurus biarmicus*, reed, population dynamics, conservation

Összefoglalás A barkóscinege *Panurus biarmicus* egy gyakori, de viszonylag kevéssé ismert énekesmadár, amely Eurázsia vizes élőhelyein fordul elő. A faj nehezen tanulmányozható, mert fészkelőhelyét – a vízben álló öreg, különösen sűrű nádasokat – nem könnyű megközelíteni és ezért a faj megfigyelése kihívások elé állítja a kutatókat. Az évek során azonban részletes ismeretek gyűltek össze a faj természetrajzáról, morfológiájáról és viselkedéséről, amelyek betekintést nyújtanak abba, hogy ez a szokatlan madár milyen adaptációk révén képes fennmaradni, sőt, kedvező körülmények között látványos mértékben gyarapodni is. 2023-ban a Magyar Madártani és Természetvédelmi Egyesület a barkóscinegét választotta az év madarának. Ennek a választásnak az apropóján, ez a cikk áttekinti a barkóscinegéről és annak egyedi jellegzetességeiről szerzett legújabb kutatási eredményeket, a populációdinamikát befolyásoló tényezőkre és a faj védelmét szolgáló lehetséges természetvédelmi kezelési stratégiákra összpontosítva.

Kulcsszavak: barkóscinege, *Panurus biarmicus*, nádas, populációdinamika, konzerváció

Department of Evolutionary Zoology and Human Biology, University of Debrecen 4032 Debrecen, Egyetem tér 1.
corresponding author, e-mail: az.lendvai@gmail.com

Introduction

The Bearded Reedling *(Panurus biarmicus)* is a small (~15 g), conspicuous passerine bird living in wetlands across Eurasia. It is an elusive bird species tied to wetlands all year round, and because its habitat is difficult to access, details of its biology have remained challenging to uncover. However, some enthusiasts of the species have gathered a surprisingly detailed body of knowledge of the species' natural history, morphology and behaviour. This information has been excellently summarised and synthesised in a German monograph by Wawrzyniak and Sohns (1986). Since its publication, many other research has been conducted on the species, and we gained new insights into the species' distribution, social behaviour, reproduction, genetics and physiology.

In 2023, BirdLife Hungary (Hungarian Ornithological and Nature Conservation Society) selected the Bearded Reedling as the 'bird of the year'. In this context, I shortly review the recent research advances on the species, focusing on the factors affecting its population dynamics and discussing potential conservation management strategies to protect the species. Putting this information together may give us a better understanding of this charming and fascinating passerine species.

General description and taxonomy

The Bearded Reedling is a unique songbird in many ways. It is not closely related to any other passerine and belongs to its own monotypic family. It is a conspicuously dimorphic species, where sexual size and colour dimorphism may already be found at the nestlings stage, which persists and becomes even more pronounced later in juveniles and adults. It forms unusually strong pair bonds shortly after fledging and remains socially attached to its partner during its life while being sexually quite promiscuous. Reedlings do not hold and defend territories but usually breed semi-colonially in loose groups, where the parents cooperate closely to rear their young, sometimes by taking care of incubation and chick rearing in different broods simultaneously. They are confined to reed stands throughout their lives and possess a number of adaptations to be highly efficient in exploiting these habitats. They are not migratory but can travel long distances (often with their social partner or in small groups) to discover and quickly colonise new areas. They are insectivorous during the summer, but to adapt to seasonal changes in conditions, they change their gut morphology and switch to a chiefly granivorous diet during the winter using a food searching behaviour that is not found in any other Eurasian bird. Unlike almost any other bird in the Northern hemisphere, they may reach sexual maturity a few weeks following their independence and might initiate a second generation within the same year. In the following sections, I review our knowledge of these aspects.

Its name (somewhat counter-intuitively) originates from the NE European area around the White Sea, called Biarmia, where the species was never known to exist. The syllable '*bi*' in the name misled many to believe that it refers to the Latin 'double' (*'bis'*) and thus means 'with two beards' or 'with two daggers' referring to the birds' two pointy, triangular feather marks, as the *'armicus'* may be confused with the Latin *'armatus'* meaning 'equipped with weapons'. This interpretation led the Dutch zoologist C. J. Temminck to name the Lanner Falcon *Falco biarmicus*, because it also possesses a similar, characteristic dark facial pattern that he thought had given the scientific name to Bearded Reedlings (Jobling 2010).

The taxonomic classification of Bearded Reedlings has undergone several changes in recent years, with different authorities proposing different taxonomic arrangements. As its former vernacular name (Bearded Tit – which is still often used) suggests, it was believed to be a relative of tits (Paridae), but its distinctive eggs, morphology, life history and behaviour soon revealed that it is not part of the true tit family (Bibby 1983). It has been variably classified among flycatchers (Muscicapidae), sylviid warblers (Sylviidae), parrotbills (Paradoxornithidae) and old-world babblers (Timaliidae). However, recent molecular studies showed that the Bearded Reedling is not closely related to any of those groups and is part of a distinct lineage that is a sister group of Alaudidae (larks) (Alström *et al.* 2006, Yeung *et al.* 2011, Alström *et al.* 2013). As a result, the species was finally moved to its own family, the monotypic Panuridae, as suggested before the advent of molecular phylogenies (Voous 1962, Bibby 1983).

Currently, three subspecies are recognised (Robson 2020). The nominate race, *P. b. biarmicus* occurs in Great Britain, France, Spain, Scandinavia, Russia, the Balkans, and Turkey. The other subspecies, *P. b. russicus* occurs in the Baltics, Poland and Belarus to Austria, NE Croatia, N Serbia and Montenegro, Bulgaria and Romania, Kazakhstan, Mongolia and China (Xinjiang, N Qinghai, W and NE Inner Mongolia, Ningxia, NE Heilongjiang). A third subspecies, *P. b. kosswigi* is used to be found in S Turkey and is now considered extinct (Saygili *et al.* 2013, Robson 2020). While the nominate race is somewhat darker, the morphological differences between these subspecies are subtle (Sluys 1983). However, even a single population may harbour morphological differences. For instance, wing length and morphology have been found to differ between sexes and age classes (Peiró *et al.* 2006). Adults have longer wings than juveniles, and females also have more convex (more round) wings than males after moult. These variations in wing morphology within the species suggest that different age groups and sexes may have somewhat different site usage. Females and juveniles with more convex wings may have enhanced manoeuvrability, while their ability to fly longer distances efficiently could be limited (Nielsen 1993, Peiró *et al.* 2006). A study of two Turkish populations showed morphological differences between the sites, but genetic analyses revealed sufficient gene flow between them (Saygili *et al.* 2013).

Habitat selection

As its new vernacular name suggests, the Bearded Reedling is a true reed specialist, and it is associated with reed *(Phragmites australis)* throughout all of its life stages and uses this habitat for foraging, nesting, roosting, etc. While the species may be found in other wetland vegetation types and sometimes may even prefer patches with mixed vegetation (Wawrzyniak & Sohns 1986), it remains mostly attached to extended reed beds. Sometimes it is stated that the species is mostly associated with cattail (*Typha* sp.) for breeding (Haraszthy 2019), but previous studies clearly indicate a preference for reed (Wawrzyniak & Sohns 1986). However, this may depend on the availability of different vegetation and may also vary between populations. For instance, in a Polish population, most nests were found in sedges (*Carex* sp.) (Stępniewski 2012), while in the Hortobágy Fishponds (Hungary), all nests were found in reed (n = 205), despite our efforts to locate nesting sites in pure or mixed cattail patches as well (Lendvai *et al.* unpublished results). Large-scale habitat analysis using remote sensing methods measuring vegetation structure directly over broad extents and at a high resolution also revealed that the most reliable predictor of the species' presence in an area is the availability of reed, especially water reed, much more than land reed (Campbell 2021).

Habitat selection may change seasonally among different life-history stages, such as breeding, wintering or dispersing, and even within a single stage depending on the activity (nesting vs. foraging) or between individuals of different body conditions (Hoi & Hoi 2001, Trnka & Prokop 2006, Saygili *et al.* 2013, Peiró 2017). During the breeding season, reedlings prefer to forage in recently grazed or cut stands of reed, where there is higher availability of food and better foraging conditions due to lower vegetation cover. However, they breed mainly in highly structured reed, and they may undertake frequent and relatively long foraging trips from their nesting sites to the relatively open areas (Beemster *et al.* 2010). During the winter, when they switch to a predominantly seed-based diet, they prefer areas with a large build-up of reed litter (Bibby 1981, Wilson & Peach 2006, Beemster *et al.* 2010) that they search through for fallen seeds and occasionally invertebrates. When they do so, they often perform a typical searching movement: they hop forward and then suddenly pull the litter backwards simultaneously with both of their legs; a behaviour referred to as 'bilateral scratching' which only occurs in taxonomically completely unrelated groups (in the Americas and tropical Africa) (Greenlaw 1977).

Although the availability of nesting sites in (often vast) reed beds may seem infinite, this picture is considerably nuanced by the structure of the reed bed. For nesting, reedlings show a marked preference for dense, clumpy, fragmented reed, often forming tussocky 'reed islands' surrounded by water or, conversely, inner clearances in otherwise big patches of reed (Wawrzyniak & Sohns 1986, Hoi & Hoi 2001, Dadam *et al.* 2014). In accordance with this preference, in three different Hungarian wetlands, reedlings were found more often in dense reed, especially at the edge of open water (Báldi & Kisbenedek 1999). More recent studies also confirmed this pattern in NW Europe, where occupied nests were more likely found in old, uncut and dense reed patches (Malzer & Hansell 2017). Even among those areas, the birds preferred patches where the degree of reed compaction or stagger reached medium to high levels (Malzer & Hansell 2017). An experiment investigating nest predation on artificial nests also underlined the importance of reed compaction in reducing nest predation, especially for predators using visual cues and also by decreasing exposure to direct sunlight (Malzer & Helm 2015). Therefore, even in large areas where the reed forms homogenous sparse coverage, the reedlings may not find suitable microhabitats for nesting. Wawrzyniak and Sohns (1986) report a few cases where reedlings occupied nests of other species, indicating a potential limitation of suitable nesting places. Improving nesting prospects by providing artificial nest sites may be especially beneficial in these places (see section 'Conservation' below).

The availability of suitable breeding, sheltering and foraging sites may vary not only within a particular wetland, but also at the landscape level. While there are enormous reed stands in some wetlands, on a large geographical scale, this habitat is essentially and inevitably fragmented as it is connected to the patchily distributed water bodies. Furthermore, on a longer temporal scale, reed stands may represent a transitional stage of succession, as with eutrophication and accumulation of leaf litter, it tends to transform into scrublands unless the leaf litter is periodically removed e.g. by regular flooding. Therefore it is expected that a bird that is confined to this sole habitat may have evolved strategies and behaviours to move between these patches depending on the current conditions. This is discussed in the next section.

Movements

The Bearded Reedling is a resident species throughout most of its range, and the species is not known for exhibiting typical migratory behaviour (but see Dürr *et al.* 1999 for a possible exception). However, a characteristic part of their life cycle is the eruptive dispersion (Spitzer 1972, Pearson 1975, Wawrzyniak & Sohns 1986, Cramp & Perrins 1994, Fenyvesi 1999a). This behaviour usually builds up as an accumulation of increasing restlessness and excitement of the birds. Some birds climb up in the reed stems and fly above the reeds with loud vocalisations, then initiate a vertical flight up to 20–30 meters while other members of the group join them, continuing loud calls. Following erratic movements, the flock eventually drops swiftly back to a different part of the reed stand. This process is repeated across several days, usually with peak intensity in the morning hours. After some days, some of these 'high-flying' does not end in plunging back to the reeds but may culminate in wandering long-distance dispersal.

Analyses of recapture data based on focal countries have concluded that this dispersal is different from migration in the sense that the eruptive flights lack a clear directional bias but instead show scattered, star-like movements out from a central location (Cramp & Perrins 1994, Hořák *et al.* 2003, Peiró 2013). Ring recovery analyses from Hungary has also confirmed this pattern (Mogyorósi 2009, Bukor 2023). Clearly, these movements are different from the traditional passerine migration pattern. For instance, unlike in many passerine species, the dispersal behaviour of the reedling does not show clear sex or age effects (Malzer 2017), although juveniles may reach the peak of these movements somewhat earlier (Gyurácz *et al.* 1997). However, a more recent analysis based on over four thousand recaptures on a Pan-European scale revealed that there is some regularity in the seasonal and directional pattern of the reedling movements. During the fall, Northern, Western and Eastern populations are more likely to move towards the South than in other directions, and the reverse direction can be observed during spring (Malzer 2017, Spina *et al.* 2022). These results suggest that despite the irregularity of their movements, there are some overall trends, and the species may be classified as a partial migrant (Malzer 2017).

Distribution and population dynamics

There have been several studies on the temporal dynamics of local Bearded Reedling populations, which have shed light on the factors that influence their distribution and abundance over time. These studies have shown that Bearded Reedlings are relatively resilient to short-term environmental fluctuations, but they can be affected by long-term changes in habitat quality and fragmentation.

One important factor that can influence the temporal dynamics of Bearded Reedling populations is weather conditions, particularly during the winter months. Harsh winters with prolonged periods of snow and ice cover can lead to reduced foraging opportunities, which can result in dramatically reduced survival and breeding success (Bibby 1983, Wawrzyniak & Sohns 1986, Cramp & Perrins 1994, Wilson & Peach 2006), but see (Surmacki & Stępniewski 2007). These adverse conditions can sometimes lead to local extinctions (extirpation), particularly in areas where Bearded Reedlings occur at the edge of their range (Wawrzyniak & Sohns 1986). For instance, in Hungary, it has been recorded that after the freezing winter of 1939, during the breeding season of 1940, only a few birds could be observed in an otherwise large breeding population. Following a temporary recovery, another harsh winter in 1941 wiped the birds from at least two large populations in Hungary with extensive reed beds (Dinnyés and Kis-Balaton) (Vönöczky Schenk 1942). Similarly, in Belgium, the species disappeared in the 1920s, reappeared only in the 1940s and became frequent twenty years later (Tahon *et al.* 1968).

Conversely, following the collapse of some of the local populations, another characteristic of the species is the ability to recolonise areas and spread quickly. A striking example of this recovery is the dynamics of the species in NW Europe, which underwent extreme fluctuations in the middle of the 20th century. For instance, the breeding population in Britain had declined significantly by the end of the 19th century due to the combined effects of habitat destruction, egg collection and the trade of adults as cage birds. This was exacerbated by several harsh winters in the 1930s and 1940s that were characterised by unusually cold weather and significant precipitation. In particular, following the winter of 1946–47, which saw prolonged heavy snowfall and icy conditions, the available food sources became so limited that the population virtually disappeared (O'Sullivan 1976). However, from the 1950s onwards, the population recovered and even became a source for rapid expansion in W Europe (Wawrzyniak & Sohns 1986).

A spectacular example of the latter phenomenon was the repopulation and the exodus following the collapse of the British population. This process has been well documented (O'Sullivan 1976, Wawrzyniak & Sohns 1986). A stable population of the species is thought to have existed in the Netherlands, but its numbers have followed the changes in the size of the extensive reed beds to a considerable extent. From 1959, the draining of polders initially resulted in the formation of vast reedlands, which was followed by the reclamation of these lands and the concomitant decrease of the reed-covered area. The rate of retreat of the reed beds was so great that over the course of a decade their initial extent was reduced by more than an order of magnitude, and it is assumed that this sudden decrease of suitable habitat contributed to the dispersion of the birds (Wawrzyniak & Sohns 1986). The initially vast reed beds are thought to have harboured a large (exceeding 10,000 pairs) population that may have served as a reserve from successive colonisation waves (Houwen 1967). During this period, reedlings appeared where they had previously been absent. Around 1965, they appeared and established new populations in Belgium and shortly afterwards in Northern and Western (even Atlantic) France, inland Germany and Poland. By the end of the 1960s, they had also appeared on the Scandinavian Peninsula, where the species had previously been entirely absent. From 1965 until the early 1970s, the colonisation of Denmark and

Sweden continued, and by 1977, the number of overwintering birds was estimated to be over 20,000 individuals (Wawrzyniak & Sohns 1986). These newly formed populations also exhibited wild year-to-year fluctuations as documented for the species in other areas, as exemplified by one Swedish population that, over four years, dropped back from an estimated 5,000 to 100 breeding pairs (Wawrzyniak & Sohns 1986).

The fluid dynamics of the populations, the disappearance of some and the colonisation of new breeding areas were not restricted to a particular period in the 20th century. This ongoing process has been recently documented in the local ornithological literature for the Southern and Eastern front of the European expansion (e.g. Fedorov 2015, Ječmenica 2016, Berezovikov & Rozenberg 2019, Koshelev & Cherkasov 2019). These sudden influxes of Bearded Reedlings may be related to weather patterns, food availability, and habitat suitability. For instance, the appearance of massive reed beds in new areas may facilitate the distribution of the species in new places (Berezovikov & Rozenberg 2019). As a consequence, trends of the European populations show a very diverse picture, with the Hungarian population trend being stable but also uncertain (Nagy 2021).

Overall, the temporal dynamics of local Bearded Reedling populations are influenced by various factors, including weather conditions, habitat quality, and fragmentation. While Bearded Reedlings are relatively resilient to short-term environmental fluctuations, they can be affected by long-term changes in their habitat. Understanding these dynamics is crucial for effective conservation management, particularly in areas where Bearded Reedlings are considered to be threatened or endangered.

Mate choice, pair-bonding and reproduction

One fascinating aspect of the Bearded Reedlings' biology is their capacity for fast reproduction, which may explain the rapid (re-)colonisation of new areas and then the rapid expansion. This may be enabled by a combination of traits that would put them on the extreme fast side of the slow-fast life history continuum (Dammhahn *et al.* 2018).

A fast life history pace starts with an early pairing. Soon after hatching, juvenile Bearded Reedlings form small groups and move around the habitat together. During this period, attachments form quickly between males and females (although typically this does not occur between siblings, but see Marin *et al.* 1994), and these alliances may develop into early pair-bonds. This phenomenon was already described by Koenig (1951), but how long these young pairs stay together and how durable their relationships have remained an open question (Wawrzyniak & Sohns 1986, Cramp & Perrins 1994).

It was also observed in the mid-20th century that these pairs move together, sometimes at large distances, e.g. birds ringed together in the Netherlands fell into a net together in NE Wales (Bibby 1983). The close association of the pair members allowed the investigation of this phenomenon based on capture-recapture data. One study found that individuals (putative pairs) captured close to each other simultaneously were often recaptured together, sometimes on several consecutive occasions, and statistical analyses showed a significant association between these individuals (Bártol & Csörgő 2000). Another study attempted to identify captive pairs by including behavioural observations prior to the birds being caught in nets, and similarly to the previous study, also showed significant association between existing pairs (Lovász *et al.* 2017). However, the latter study was also able to show that a significant proportion of pairs formed at a young age remained together for longer periods, confirming previous hypotheses that reedlings form persistent, socially monogamous relationships. Based on the sex distribution of the captured animals, statistical probability calculations can also be used to infer the pair-bonds from mark-recapture datasets. Using this method, pair-bonds in a significant proportion of juveniles could be identified in two European populations (Brocchieri *et al.* 1992).

The early establishment of stable pair-bonds may be an important element in the successful reproduction of reedlings. Long-term pair-bonding can increase reproductive success and fitness in many species (Sánchez-Macouzet *et al.* 2014). In socially monogamous species, individuals that maintain pair-bonds over multiple breeding attempts are often able to improve reproductive success compared to conspecifics that switch partners (Gabriel & Black 2012). These benefits can manifest in Bearded Reedlings. The formation of stable pairs in the previous year facilitates an early onset of reproduction because they do not have to “waste time” on choosing a mate in spring (Bibby 1983). Egg-laying typically starts around in early April in many European populations (Wawrzyniak & Sohns 1986). However, it should be noted that some pairs may start breeding significantly earlier. For instance, in 2016, in the Hortobágy Fishponds, Hungary, we observed a fledgling on the 4th of April, which, even based on the most conservative estimate, suggests a clutch initiation in early March (Lendvai *et al.* unpublished data). This may precede by at least two weeks the earliest onset of laying found in the published literature (Stępniewski 2012).

Such an advancement of breeding, even in a species that starts reproduction early in the season, may be the consequence of the well-coordinated cooperation of pair members. It was experimentally demonstrated that longer periods of forming pair-bonds lead to better overall breeding performance than those with shorter periods, resulting in more synchronised nest building, the higher success rate in nesting, and earlier clutch initiation (Griggio & Hoi 2011). Importantly, these differences were not due to different efforts of the parents, highlighting the importance of pair coordination. The effect sizes of these factors are far from subtle: birds in well-established pair-bonds may start up to one month earlier and can have twice as many offspring in a season than hastily paired individuals, conferring a strong evolutionary advantage of strong social monogamy (Griggio & Hoi 2011).

If pair-bonds are that important, we may expect that birds are ready to strengthen it during hard times. This is exactly what happens, as an elegant experiment demonstrated (Hoi & Griggio 2012). When monogamous pairs were isolated and presented with an unpaired solitary conspecific, the pair members increased physical contacts with each other to reinforce their pair-bond. However, this response depended on the sex of the unpaired bird. Females initiated more contacts with their mates only if the single individual was a female and thus, a potential competitor. In contrast, male partners increased the number of contacts with their mates if the competitor was a male, but also if the lone individual was a female that was less attractive than their mate. These results suggest that reedlings adjust their pair-bond investments in response to the presence, and to a lesser extent to the attractiveness of a potential rival (Hoi & Griggio 2012). Social cohesion between the pair members may be reinforced by vocalisations, clumping together, and mutual allopreening (Tóth *et al.* 2015).

Given the importance of the relationship, choosing a good-quality mate is crucial with respect to fitness. As reedlings do not hold territories, mate choice is based on individual quality and their decision is not determined by resources. Since pair formation already happens in juveniles, one might expect to find sexual dimorphism in juveniles. While this is rare in passerines, reedlings represent a conspicuous case for such a phenomenon (Surmacki *et al.* 2015).

Males and females have different bill colouration that is already noticeable at the nestling stage and can be used to reliably determine the sex of the chicks (Darolová *et al.* 2008). This difference in bill colouration remains after fledging and persists until adulthood. While juvenile males do not have 'beards' as adults do, they have black lores that also shows sexual dimorphism. Juvenile males have larger and more conspicuous, darker lores, a more extensive melanised back patch, while they also have significantly longer tails and are in general, larger and heavier than females (Surmacki *et al.* 2015). Back patch size in juvenile males was also related to their body condition, suggesting that these sexually dimorphic traits may serve as condition-dependent signals.

In adults, two important feather quality markers are the "beard" of the males and the length of the tail (in both sexes). Beard length is negatively related to parasite load and is the best predictor of dominance in male-male competition (Hoi & Griggio 2008). Nevertheless, it is a static signal that is not related to body condition (Hoi & Hoi 2001, Peiró 2021), and it only changes during the annual moult, whereas dominance behaviour is much more dynamic and reflects the actual state of the individual. When females had to choose between males of experimentally manipulated beard length and males with different social status (dominant vs. subordinate), they showed a clear preference for long-bearded males, with dominance status having only a slight complementary effect (Hoi & Griggio 2011).

Beard length may play an important role in males' life if their partner dies. Females have higher mortality than males (Peiró 2011), and if an older male loses his partner, it is frequently observed that he joins juvenile flocks and forms a partnership with a new mate (Hoi & Griggio 2008, Lovász *et al.* 2017). Having an attractive long beard in this context may be advantageous. However, instead of having the largest beard possible, having any beard in the first place may be even more important. Juveniles and adults all perform a complete moult at the end of the summer, and the sequence of the moult is strictly regulated (Steiner 1971, Buker *et al.* 1975, Pearson 1975, Massi & Spina 1996). The head feathers and the beards are among the last body parts moulted, so completing the moult sooner and get it ready when pair formation and mate choice happens may be more important than having a large beard but too late (Hoi & Griggio 2008). (For the physiological mechanisms that may allow faster development of the sexually selected ornaments, see the section 'Physiology' below). Beard length is also positively related to extra-pair copulations (see below) and negatively associated with parental contributions (both incubation and chick provisioning) (Hoi & Hoi-Leitner 1997). These results clearly indicate that sexual selection plays an essential role in the evolution of this ornament.

Another trait that is under sexual selection in Bearded Reedlings is the tail. Males have longer tails than females in both adults and juveniles (Cramp & Perrins 1994, Surmacki *et al.* 2015). Females prefer males with longer tails, and while males may also find short-tailed females less attractive, their preference for long traits may be less pronounced than in females (Romero-Pujante *et al.* 2002). Therefore, tail length seems to be a quality indicator in both sexes and is a subject of mutual mate choice. Females with longer tails have better body condition and larger clutch sizes (Hoi & Hoi-Leitner 1997).

Apart from sexual selection, tail length is also affected by natural selection, as the length of the tail affects movement agility. In an experiment where the tail was shortened, individuals used the characteristic straddle posture (when they use both legs to hold on to different reed stems) less frequently (Romero-Pujante *et al.* 2005). However, tail length (and also beard length) is not related to the birds' social position or prestige in the flock (Tóth *et al.* 2015).

Both adults and juveniles bear multiple ornaments, bringing the question of how individuals evaluate their information content during mate choice. This question was investigated in an experiment where manipulation of these two traits in males was conducted to convey conflicting messages about the quality of the bearer. When females were presented with contrasting information about beard length and tail length, a preference polymorphism emerged, with some females showing a strong preference for the tail while others for the beard (Griggio *et al.* 2016).

While long tail may be a quality indicator in both sexes, the fact that males do not show an unambiguous preference for long-tailed females (as described above) may be explained by the costs of having a high-quality female (Hoi & Hoi-Leitner 1997). High-quality females (with longer tails and better body condition index) breed in loose colonies, while some individuals are solitary breeders, building nests further away from the colony (Hoi & Hoi-Leitner 1997). The colonial females engage in a 'catch me if you can' game that puts their partners to a thorough test.

This characteristic behaviour is the chase-flight, a form of 'flirting-teasing' behaviour initiated by the females. The sequence of this behaviour usually starts with the female uttering a distinctive soliciting call that drives her partner and other males in the vicinity to attempt to copulate with her. However, before this could happen, the female suddenly escapes and flies up above the reeds while emitting calls, with her mate pursuing her. Other males join the chase (up to 12 males have been observed) (Birkhead & Hoi 1994). Eventually, the female turns suddenly and dives back into the reeds. Here the male that managed best to keep up with her has a chance to copulate, who is not necessarily the social mate. This phenomenon leads to a high degree of extra-pair paternity, although males with longer beards are better at protecting their paternity (Hoi & Hoi-Leitner 1997). Experimental tests have shown that females in their fertile period (nest-building and egg-laying) and high-quality females are more likely to initiate these chase-flights (Hoi 1997, Hoi & Hoi-Leitner 1997). Females therefore seem to incite male-male competition to assess the quality (in terms of virility and vigour) of males and thus, acquire extra-pair fertilisations to obtain 'good genes'.

This idea is further corroborated by the observation that males in this species have testes 70% larger than predicted by their body mass and they possess a phallus-like copulatory organ that is unique among passerines, while the females' reproductive tracts do not show specific adaptations to avoid unwanted copulations (Birkhead & Hoi 1994, Sax & Hoi 1998). Furthermore, females have limited capacity to store sperm and have a relatively high rate of sperm loss that requires frequent copulations to ensure the successful insemination of the clutch during egg-laying (Sax *et al.* 1998). Taken together, colonial breeding may represent opportunities for the females to acquire extra-pair copulations. Colonial breeding is also associated with an increased incidence of conspecific brood parasitism in relation to nesting density (Hoi *et al.* 2010).

Once the pair is established, they soon start building the nest (with both sexes participating) and the female starts egg-laying. Eggs are white to creamy-white with fine dark brown line markings and speckles. Egg dimensions (based on 125 eggs from 19 nests collected in Hungary between 1926–1960): length 15.8–19.0 mm, breadth 13.1–15.1 mm, volume 1.42–2.15 cm^3 (Solti 2010). Incubation usually starts with the penultimate egg, and both parents incubate. Nest building continues during incubation, especially lining up with feathers (Koenig 1951, Wawrzyniak & Sohns 1986). Clutch size is usually between 4 and 8 eggs (in Hortobágy, average 5.58 ± 0.88 SD, Lendvai *et al.* unpublished data, which is in agreement with other populations, but lower than 6.77 ± 1.0 reported earlier from Hungary (Wawrzyniak & Sohns 1986, Haraszthy 2019). Large clutches (up to 12 eggs) may represent egg dumping, which occurs frequently in the species (Wawrzyniak & Sohns 1986, Hoi *et al.* 2010). Clutch size may show significant yearly variation, and the repeatability of egg measurements is moderate, suggesting considerable phenotypic plasticity (Surmacki *et al.* 2003).

The chicks hatch about 10–13 days after laying the last egg. The secondary sex ratio of offspring (around the age of 7 days) from three populations was slightly, but not significantly female-biased. In a Spanish population, the juvenile sex ratio was also close to equity (Peiró 2011). However, in a study across three populations in Central Europe (Austria, Slovakia and N Italy), almost a third of the nests contained single-sexed broods, which deviated significantly from the expected under a binomial distribution (Darolová *et al.* 2009). Female nestlings tend to hatch sooner and have higher initial body mass than males, which, in turn, develop faster. By modifying the hatching order, female parents may give their daughters a head start in intra-brood competition (Darolová *et al.* 2008). Both parents feed the chicks, which fledge around 12–14 days, although chicks may leave the nest (force-fledging) earlier (after 9 days of age) if disturbed (Wawrzyniak & Sohns 1986, Haraszthy 2019).

There are some reports on cooperative breeding (Koenig 1951), but this has not been confirmed. Different adults or juveniles may often visit a nest of a focal pair, but whether they actively feed the young has not been demonstrated convincingly. In the Hortobágy Fishponds, in one nest with nestlings, we also trapped an adult individual that was known not to be either of the parents (which were both marked at this point), but we could not prove that this third adult was provisioning. In video recordings of several nests with marked parents, we never observed foreign individuals assisting in nestling provisioning (Lendvai *et al.* unpublished results).

Reedlings are multi-brooded. The number of subsequent broods may vary, usually 2–3, but it may be up to four broods in a season if environmental conditions are favourable (Buker *et al.* 1975, Wawrzyniak & Sohns 1986). Although the breeding season of the reedlings is long – birds may still breed in August (e.g. Surmacki & Stępniewski 2007), to pull this off, the parents may need to resort to unusual solutions.

The stable pair-bond described above allows for very efficient cooperation between the parents, and this, in turn, enables the division of labour between the parents and initiating overlapping broods. When the nestlings are close to fledging, the couple may start building a new nest, sometimes giving "the impression of having been put together in undue haste" (Bibby 1983) and start egg-laying. A systematic study in Poland found that overlapping nesting attempts by the same couple are relatively frequent and consist of a median of 10% of the broods (Stępniewski & Halupka 2018). However, this feat was only observed when the population density was low. In years with high population densities, overlapping broods were never observed (Stępniewski & Halupka 2018). By initiating broods simultaneously, finishing nest building during incubation, sometimes reusing the same nest for subsequent breeding (Stępniewski 2003) and rearing their young to independence quickly, reedlings may compress all breeding stages and maximise the number of breeding attempts in a season.

In addition to these already remarkable attributes, reedlings possess another trait that further distinguishes them from other species, which is an impressive feature of their reproductive biology. As discussed above, juveniles pair up shortly after fledging, and it has been suggested that these juvenile pairs may start reproducing later in the season when they are born. This was indicated in two earlier observations (Spitzer 1972, Björkman 1975), and in captivity, juvenile pairs have been confirmed to build nests and lay eggs (Griggio & Hoi 2011), but it remains uncertain if these pairs can successfully finish a breeding attempt. Despite intensive field efforts, no such case has been unambiguously reported from the field in the past 50 years, so the phenomenon may be genuinely rare. Similar to overlapping broods discussed above, it is possible that this strategy occurs only in special years, with low breeding density, or during the initial phase of population establishment. Regardless of its frequency, the mere existence of this pattern, even if it exists only as a preparational step for the young couples for the following breeding season is remarkable, as no bird in the Northern Hemisphere has two generations in one year, with the possible exception of the Zitting Cisticola *(Cisticola juncidis)* (Ueda 1985).

Taken together, a suite of reproductive traits put the Bearded Reedling on the fast extreme of the slow-fast life history continuum. These include an early pair formation, strong life-long pair-bonds that allow the early onset of breeding, optimising parental cooperation and division of labour facilitating multiple, sometimes overlapping breeding attempts and eventually a juvenile reproduction, and thus, potentially a second generation within a season. All of these may contribute to the long-term resilience of the species in the face of environmental variation and the ability to increase population size, which is counterbalanced by their sensitivity to environmental conditions and high mortality rates.

Parasite infections

Apart from the climatic challenges, bearded reedlings, like most passerines also need to cope with the risk of parasitic infections, which can threaten their long-term survival. As an obligate wetland-dwelling species, Bearded Reedlings live year-round in habitats that harbour a vast diversity of mosquitos that transmit various *Plasmodium* and *Haemoproteus* lineages. Various songbirds living in much drier habitats often have around 60% prevalence of malaria (Malavi database: http://mbio-serv2.mbioekol.lu.se/Malavi). In light of these data, it is surprising that we found an extremely low prevalence of avian malaria infection in two Central European populations 3.9% and 0% in Austria and Hungary, respectively: Szöllősi *et al.* (2020) and these results were corroborated by other populations: 3.8% in Bulgaria (Dimitrov *et al.* 2018), 10% in Sweden (Nilsson *et al.* 2016) and 0% *Plasmodium* while 3.4 and 10.3% in different *Haemoproteus* strains, respectively (Ciloglu *et al.* 2020). These results suggest two possible explanations. First, reedlings may be extremely sensitive to malaria infections with almost all infected individuals suffering high mortality (Szöllősi *et al.* 2020). While at the moment, we cannot rule out this possibility, given the large abundance and diversity of vector fauna in their habitat, if malaria eliminated all infected individuals, that would easily drive the population to extinction in a short time. The intriguing alternative explanation is that reedlings may be resistant to malaria infection or that birds are able to avoid or clear the infection quickly, which makes them an interesting potential model for the behaviour, physiology and genetics of immunity (Szöllősi *et al.* 2020).

Despite the remarkably low incidence of blood-borne parasites, Bearded Reedlings are hosts to a number of ectoparasites, including some host-specific species. The parasite causing the most conspicuous adverse effects in the birds is a newly described mite species *Harpirhynchus dusbabeki* (Bochkov & Literák 2006). This mite may have been previously misidentified as *H. nidulans,* and it induces the development of voluminous dermal cysts under the birds' wings (Henry *et al.* 2004, Bochkov & Literák 2005, Literák *et al.* 2006). The cysts take months to develop and therefore are only found in adults and show marked seasonal and geographical variation (Henry *et al.* 2004, Literák *et al.* 2005). While the mites do not cause immediate mortality and the fitness costs induced by them are not obvious, at least there is no observable effect on body mass and feather moult (Henry *et al.* 2004).

In addition to *Harpirhynchus dusbabeki* / *nidulans*, reedlings are hosts of feather mites *(Proctophyllodes pinnatus)* (Vágási & Tökölyi 2005), and may be infested with chigger mites *(Blankaartia acuscutellaris)*. In a population in southwest Slovakia, chigger mites were present on Bearded Reedlings throughout the year, but their prevalence and intensity of infestation were higher in the breeding season (Trnka *et al.* 2023). Although mite infestation in Bearded Reedlings has a relatively high prevalence and intensity, there seem to be no discernible differences in body condition between infested birds and those that are not. Therefore, it is suggested that infestation by *B. acuscutellaris* may not have serious negative effects on the health of the host, although the presence of ectoparasites could still have adverse effects, such as reducing the host's ability to cope with other stressors or infections. One study found 33 different mesostigmatic mite species in Bearded Reedlings nests collected from Austria, Slovakia and Italy, most of the mites belonging to the parasitic *Ornithonyssus sylviarum* species (Krištofík *et al.* 2007).

Another potential threat to reedlings is infection by the ticks, *Hyalomma rufipes*, which has been reported in recent years (Keve *et al.* 2023). This tick species is known to carry various diseases, and its presence in reedling populations raises concerns for potential health impacts. Molecular analyses of the collected ticks showed that all *H. rufipes* individuals collected in Hungary had identical haplotypes, indicating a common maternal origin. Moreover, the study found that *H. rufipes* haplotypes were site- and population-specific, suggesting a potential founder effect in the population of *H. rufipes* in the southwestern part of Hungary. The apparent unengorged state of a *H. rufipes* larva on one of the birds suggests that the tick infestation did not originate from abroad but was acquired locally.

While none of these parasites seems to exert immediately harmful effects on the reedlings (with the potential exception of haemosporidian, see above), the effects of parasites on their hosts may be more subtle and indirect or dependent on their life-history stage, therefore, it is possible that in conjunction with other factors, they may contribute to variations in survival or fecundity.

Physiology

Recent years have seen an increase in the number of studies examining hormonal regulation in Bearded Reedlings, shedding light on the species' physiology and behaviour. One such critical hormonal aspect is the evolutionarily highly conserved insulin-like growth factor-1 (IGF-1) signaling pathway, a complex signaling network processing information about the internal state of the organism and regulating cell growth, differentiation, and survival. The IGF-1 system is extensively studied in laboratory model organisms but is much less known in free-living vertebrates, let alone birds (Lodjak & Verhulst 2020, Regan *et al.* 2020). A handful of studies in wild birds have investigated how IGF-1 affects growth in nestlings, while its role in adults has remained unknown. Therefore, the Bearded Reedling became one such system, where information is accumulating about the regulatory role of IGF-1 in avian systems.

In an initial experiment, we investigated the change in circulating levels of IGF-1 and corticosterone in response to stress in adult wild Bearded Reedlings. We found that during capture and handling stress, corticosterone levels increased, as seen in many other birds (Bókony *et al.* 2009). At the same time, IGF-1 levels significantly decreased, independently from glucocorticoids (Tóth *et al.* 2018). A follow-up experimental increase of corticosterone using a non-invasive oral manipulation revealed no effect on IGF-1 levels, suggesting that the hypothalamic-pituitary-somatotropic (HPS) axis producing IGF-1 may play an important role as a regulator of life-history decisions in response to unpredictable stressors (Tóth *et al.* 2018).

Another experiment investigated the role of IGF-1 during periods of food shortage by altering the feeding regimes in captive Bearded Reedlings. The birds lost mass under food restriction, but the magnitude of mass change depended on the initial dietary conditions, showing that individuals may anticipate future resource availability based on previous experiences and adjust their physiology accordingly (Tóth *et al.* 2022). We also found large individual differences in IGF-1 reaction norms, with some individuals increasing

IGF-1 levels in response to a restricted diet while others showed no response or decreased IGF-1 levels. These individual differences were explained by differences in average body mass, with heavier individuals having higher IGF-1 levels during the control treatment and being more likely to decrease IGF-1 levels in response to dietary restriction than lighter individuals. Males also had higher IGF-1 levels than females, but this may be due to their size differences rather than sexual differences per se (Tóth *et al.* 2022).

Finally, in a series of experiments, we investigated the role of IGF-1 in the formation of new feathers and the development of plumage ornaments. Using a novel experimental method (Mahr *et al.* 2023a), we achieved a sustained elevation of circulating IGF-1 levels using a single subcutaneous injection. In one experiment, we found that in naturally moulting juvenile reedlings, the IGF-1 treatment did not affect the feather growth rate of growing primary feathers but increased the number of feathers being moulted simultaneously and advanced the stage of moult. The birds with increased IGF-1 had better-quality feathers than the control group, as measured by the lower number of fault bars. An increase in IGF-1 may alter moult intensity by initiating the renewal of several feathers at once, shortening the overall moulting time, which may be critical in getting the plumage ready by the time of mate choice (see details above about the importance of early pairing for this species). However, this may imply costs in terms of IGF-1-induced oxidative stress (Lendvai *et al.* 2021).

This latter assumption was investigated in a different experiment, where we simulated elevated IGF-1 levels in captive Bearded Reedlings and found that increased IGF-1 causes short-term sex-specific oxidative damage. Males were more susceptible to IGF-1-induced oxidative stress than females and the capacity to quickly restore oxidative balance increased survival prospects in males. The study highlights a sexual difference in the physiological susceptibility to IGF-1 variation, which is intriguingly the opposite of earlier findings on laboratory mammals, where the mortality pattern is reversed compared to birds including Bearded Reedlings, where females generally incur higher mortality (Lendvai *et al.* 2023).

These results line up well with the observation that sexually selected ornaments seem to be related to IGF-1 levels in reedlings. A significant correlation was found between IGF-1 levels during moulting and the development of multiple ornamental plumage traits in male and female Bearded Reedlings. The results indicate that higher IGF-1 levels positively affected male structural plumage colours and tail feather length in males but not melanin-based ornaments, such as the beard length. Female tail length was also unrelated to IGF-1 levels. This is the first study that suggests that IGF-1 may play a role in the expression of sex-specific plumage ornaments in a bird species (Mahr *et al.* 2020). Because males seem more sensitive to IGF-1-induced oxidative costs, this mechanism may ensure the honesty of these sexual signals. These results are also corroborated by recent experiments, where the development of the structural colouration was affected by exogenously increased IGF-1 levels (Mahr *et al.* 2023b).

Taken together, IGF-1 in bearded reedlings may mediate life-history trade-offs between somatic growth (feather growth and the development of sexually selected plumage ornaments) and longevity (via IGF-1-induced oxidative stress in males).

Conservation

As noted earlier in this review, the Bearded Reedling show a combination of resilience and sensitivity to environmental effects. While in the long run, the species has managed to survive various environmental changes and achieved a widespread distribution, and thus, currently classified as ‘least concern’ by IUCN, local populations may be subject to dramatic declines and potential extirpation. Some of these cases in the recent past have been well documented. For instance, the population in Sicily went extinct by 1958 (Sluys 1983), just before the large range expansion in Western and Northern Europe detailed in the section ‘Distribution and population dynamics’. More recently, the coastal populations in Spain suffered a dramatic decline, where the population collapsed and is predicted to become extinct shortly (Belenguer *et al.* 2016, Peiró 2022). The most well-documented fluctuation however, happened in the recently colonised high-latitude population in Leighton Moss, UK.

The first Bearded Reedlings arrived in Leighton Moss in 1965, during the great NW European expansion of the species (see 'Distribution and population dynamics'), and confirmed breeding from the early 1970s, then the population gradually stabilised to around 35 pairs in the 1990s (Wilson 1993). Later, the breeding population further increased to above 60 pairs by 2000 (Wilson & Peach 2006). Over the cold and rainy winter of 2000/2001, the leaf litter, which serves as a main reserve for seeds that the birds feed upon during the winter, got flooded, rendering the seeds unavailable (Bibby 1981, Wilson & Peach 2006). These events caused a general food shortage for the birds, resulting in suboptimal foraging options with increased exposure to predators, and the combination of these effects culminated in a massive drop in body mass and eventually 96–98% mortality (depending on the age class) and a quasi-extinction from which the population started to recover over the following years (Wilson & Peach 2006).

The collapse of the Leighton Moss population and the management of this population holds several crucial takeaways. First, changes in the population size can only be recognised if there is an adequate monitoring protocol in the population. The Leighton Moss population was subject to a systematic sampling of the individuals and their reproductive effort for over several years. The cryptic lifestyle of the reedlings, the lack of territories and their inhomogeneous breeding distribution make it challenging to estimate their abundance correctly (Hoi & Hoi 2001, Surmacki 2003, Surmacki & Stępniewski 2003, Vadász *et al.* 2011, Peiró 2013, Dadam *et al.* 2014, Malzer 2017). Systematic ringing and point counts from elevated observation points may yield adequate data, although the applicability of these methods may largely depend on the specific local circumstances and the timing of the census over the season and within a day (Trnka *et al.* 2006, Malzer 2017), and they are prone to the presence of transients in the population (Peiró 2017). Estimating breeding efforts directly may provide the most direct estimates of the nesting populations (Wawrzyniak & Sohns 1986, Wilson & Peach 2006), although this requires significant efforts due to the limited accessibility of nesting sites of the species. An alternative method could be the direct estimates of productivity based on captures of juveniles and using the iris colouration to indicate their age (Wilson & Hartley 2007).

Second, the temporary population collapse draws attention to the importance of food supplies, especially during winter flooding or large snow cover that may make the winter seed reserves unavailable for the birds. As mentioned earlier, during the winter, the gut morphology of the reedlings adapts to a predominantly seed-based diet, which also requires the ingestion of small grit to facilitate the physical grinding of the food in the gizzard. An easy conservation management step that helps birds to find this useful resource is the installation of gritting platforms in the reed bed. Several of these platforms have been deployed in Leighton Moss, and the birds quickly adapted to them and used them regularly between September and December (Wilson 2014). These gritting trays also provide an ideal opportunity for a standardised collection of visual resighting of colour-ringed individuals that may alleviate the aforementioned difficulties with abundance estimation. Having the birds adapted to the gritting trays may also provide the opportunity to supplement the grit with seeds. Although this has not been reported for Bearded Reedlings, the effects of bird feeders on the winter survival of resident passerines is well known. Enriching the gritting trays or installing separate feeders may not affect the birds' survival under 'normal' conditions, but in case of a sudden drop in food availability, they may save the birds from starvation.

Another conservation intervention implemented in Leighton Moss is the installation of artificial 'nestboxes' made of reed (Wilson 2005). Depending on their location within the reed stand, the occupancy of these nestboxes may have reached 68% (Wilson 2015). Reed-based artificial nesting sites have been used for centuries in Central Europe. For instance, fishermen in Hungary used to break a bundle of reed stems and tie a knot from them to signal the location of their fish traps. As an eventual 'side-effect', these structures provided shelter and attracted various wetland species for nesting, including reedlings. Nowadays, these reed knots are explicitly used to provide additional nesting sites for reedlings (Kovács 1981, Fenyvesi 1999b).

A final and more complex consideration of the conservation of the species is the management of their habitat. As detailed above, Bearded Reedlings are highly specialised to reed-covered wetlands and are well-adapted to live in this habitat throughout their lifetime and exploit its resources. Therefore, the presence and breeding success of reedlings may provide insight into the condition and functioning of the wetland ecosystem as a whole (Malzer 2017). Since Bearded Reedlings are affected by different successional stages of reed stands (Beemster *et al.* 2010), efficient management of the reed for either economic harvesting or optimising between different needs of species in the wetlands requires careful planning. Cutting parts of the reed bed may have beneficial effects in terms of increased production, a more dense structure of the reed, and an increase in invertebrate biomass (Poulin & Lefebvre 2002). However, cutting the reed makes it unsuitable for reedlings as breeding sites, at least early in the season (Poulin & Lefebvre 2002, Vadász *et al.* 2008). Experience from the UK has shown biennial cutting (double wale) to be a good middle ground between conservation and commercial interests. However, in the Mediterranean region, the only viable long-term option seems to be a combination of annually cut and never cut reed patches. It is also possible that an optimal combination of cut and uncut reed patches could provide a similar conservation value to unmanaged reed beds (Poulin & Lefebvre 2002). Apart from cutting, appropriate management of water levels and water quality is also important (Peiró 2020).

It is unlikely that a wetland is only managed to protect Bearded Reedlings, therefore, the management strategy also needs to consider the potentially conflicting needs of different target species (Malzer & West 2015, Wilson 2015). However, if conservation management aims to protect Bearded Reedlings in a given habitat, it can only be achieved efficiently if we take into consideration the intricate relationships between their life history, behaviour, physiology and their environment and synthesise the available information of this remarkable species. This review hopefully helps achieve this goal.

Acknowledgements

I would like to thank Tibor Csörgő for the invitation to write this review. Our research on the reedlings would not have been possible without the work of graduate students and postdocs: Zsófia Tóth, Katharina Mahr, Orsolya Vincze and Nürettin Beşer. Thanks also go to Herbert Hoi for advice, discussions, providing unpublished data and for collaborations, and to Imre Molnár, Gergely Jerkovich, Brigitta Csernus for their help in the lab. Many students helped in the field over the years, and I am also grateful for their work: Katalin Bodnár, Noémi Bujnóczki, Sándor Brian Bürgi, Zsolt Kiss, Csaba Nagy, Gyula Ölveczki, Tamás Judák, Levente Őri, Anna Rácz, Gábor Rédai, Katalin Urbán, Anna Szabados, Gyula Péter Molnár, Hanga Hegyes. I am grateful for the Hortobágyi Halgazdaság and Hortobágy National Park Directorate (especially János Tar and Pál Tóth) for supporting us and for allowing us to work on their property. Two anonymous reviewers provided constructive comments on earlier versions of this work. I thank Arne Hegemann, Beata Apfelbeck and Zoltán Németh for motivation and 'mild pressure' to write up the manuscript. I was supported by grants of the National Development, Research and Innovation Fund (OTKA K139021 and 2019-2.1.11-TÉT-2019-00043).

References

Alström, P., Ericson, P. G. P., Olsson, U. & Sundberg, P. 2006. Phylogeny and classification of the avian superfamily Sylvioidea. – Molecular Phylogenetics and Evolution 38(2): 381–397. DOI: 10.1016/j.ympev.2005.05.015

Alström, P., Olsson, U. & Lei, F. 2013. A review of the recent advances in the systematics of the avian superfamily Sylvioidea. – Chinese Birds 4(2): 99–131. DOI: 10.5122/cbirds.2013.0016

Báldi, A. & Kisbenedek, T. 1999. Species-specific distribution of reed-nesting passerine birds across reed-bed edges: effects of spatial scale and edge type. – Acta Zoologica Academiae Scientiarum Hungaricae 45(2): 97–114.

Bártol, I. & Csörgő, T. 2000. A barkóscinege *(Panurus biarmicus)* párképzési dinamikája fogás-visszafogás adatok alapján [Dynamics of pair formation of the Bearded Tit *(Panurus biarmicus)* on the basis of capture-recapture data]. – Ornis Hungarica 10: 71–77. (in Hungarian with English Summary)

Beemster, N., Troost, E. & Platteeuw, M. 2010. Early successional stages of reed *Phragmites australis* vegetations and its importance for the Bearded Reedling *Panurus biarmicus* in Oostvaardersplassen, The Netherlands. – Ardea 98(3): 339–354. DOI: 10.5253/078.098.0308

Belenguer, R., Iborra, G. M. L., Jambrino, J. D. & Àlvaro, J. C. 2016. Dramatic decline of the Bearded Reedling *Panurus biarmicus* in Spanish Mediterranean wetlands. – Animal Biodiversity and Conservation 39(1): 17–27. DOI: 10.32800/abc.2016.39.0017

Berezovikov, N. N., & Rozenberg, G. V. 2019. Залёт усатой синицы Panurus biarmicus в Бухтарминскую долину на Южном Алтае. [Appearance of the Bearded Tit Panurus biarmicus to the Bukhtarma Valley in the Southern Altai.] – Russian Ornithological Journal, 28(1861), 5820–5823. (in Russian)

Bibby, C. J. 1981. Food supply and diet of the Bearded Tit. – Bird Study 28(3): 201–210. DOI: 10.1080/00063658109476724

Bibby, C. J. 1983. Bearded Tit. – British Birds 76(12): 549–563.

Birkhead, T. R. & Hoi, H. 1994. Reproductive organs and mating strategies of the Bearded Tit *Panurus biarmicus*. – Ibis 136(3): 356–359. DOI: 10.1111/j.1474-919X.1994.tb01107.x

Björkman, G. 1975. Skäggmesen *Panurus biarmicus* i Tåkern [Bearded Reedlings at the Tåkern Lake]. – Vår Fågelvärld 34: 296–310. (in Swedish)

Bochkov, A. & Literák, I. 2006. A review of the European Harpirhynchidae (Acari, Prostigmata) with the description of a new species. – Acta Parasitologica 51(2): 136–142. DOI: 10.2478/s11686-006-0021-9

Bókony, V., Lendvai, Á. Z., Liker, A., Angelier, F., Wingfield, J. C. & Chastel, O. 2009. Stress response and the value of reproduction: are birds prudent parents? – American Naturalist 173(5): 589–598. DOI: 10.1086/597610

Brocchieri, L., Matessi, C. & Marin, G. 1992. Inference of pair bonds from capture data based on low variation of the sex ratio among catches. – American Naturalist 140(3): 492–508. DOI: 10.1086/285423

Buker, J. B., Buurma, L. S. & Osieck, E. R. 1975. Post-juvenile moult of the Bearded Tit, *Panurus biarmicus* (Linnaeus, 1758), in Zuidelijk Flevoland, the Netherlands (Aves, Timaliinae). – Beaufortia 23(306): 169–179.

Bukor, Z. 2023. A Velencei-tó barkóscinegéi [Bearded Tits of Velence lake]. – Madártávlat 30(1): 6–7. (in Hungarian)

Campbell, A. 2021. Using LiDAR to assess the influence of fine-scale habitat structure on the abundance of the Bearded Reedling. – MSc Thesis, University of Amsterdam

Ciloglu, A., Ergen, A. G., Inci, A., Dik, B., Duzlu, O., Onder, Z., Yetismis, G., Bensch, S., Valkiūnas, G. & Yildirim, A. 2020. Prevalence and genetic diversity of avian haemosporidian parasites at an intersection point of bird migration routes: Sultan Marshes National Park, Turkey. – Acta Tropica 210: 105465. DOI: 10.1016/j.actatropica.2020.105465

Cramp, S. & Perrins, C. M. 1994. Birds of the Western Palearctic (BWP): Handbook of the Birds of Europe, the Middle East and North Africa, Vol. 7. – Oxford University Press. *Panurus biarmicus,* pp. 88–100.

Dadam, D., Leech, D. I., Clark, J. A. & Clark, N. A. 2014. Bearded Tit *(Panurus biarmicus)* survey at Stanny House Farm. – British Trust for Ornithology, The Nunnery, Thetford, Norfolk

Dammhahn, M., Dingemanse, N. J., Niemelä, P. T. & Réale, D. 2018. Pace-of-life syndromes: a framework for the adaptive integration of behaviour, physiology and life history. – Behavioral Ecology and Sociobiology 72(3): 62. DOI: 10.1007/s00265-018-2473-y

Darolová, A., Krištofík, J. & Hoi, H. 2008. Female biased hatching order in nestling Bearded Tits: a compensatory maternal tactic to reduce developmental differences. – Folia Zoologica 57(3): 231–239.

Darolová, A., Krištofík, J. & Hoi, H. 2009. Extreme brood sex ratios in Bearded Tits *Panurus biarmicus*. – Ibis 151(1): 191–195. DOI: 10.1111/j.1474-919X.2008.00879.x

Dimitrov, D., Ilieva, M., Ivanova, K., Brlík, V. & Zehtindjiev, P. 2018. Detecting local transmission of avian malaria and related haemosporidian parasites (Apicomlexa, Haemosporida) at a Special Protection Area of Natura 2000 network. – Parasitology Research 117(7): 2187–2199. DOI: 10.1007/s00436-018-5906-7

Dürr, T., Sohns, G. & Wawrzyniak, H. 1999. Ringfundauswertung in Ostdeutchland beringter bzw. kontrollierter Bartmeisen *(Panurus biarmicus)* [Ring recovery analysis in Eastern Germany of ringed or controlled Bearded Tits *(Panurus biarmicus)*]. – Vogelwarte 40: 117–129. (in German)

Fedorov, V. A. 2015. Новые случаи гнездования усатой синицы Panurus biarmicus в Санкт-Петербурге. [New cases of nesting of the bearded reedling Panurus biarmicus in St. Petersburg] – Russian Ornithological Journal, 24(1145), 1773–1781. (in Russian)

Fenyvesi, L. 1999a Csapattoborzó barkóscinegék [Group recruiting in Bearded Reedlings]. – Madártávlat 6(1): 9. (in Hungarian)

Fenyvesi, L. 1999b Fészekalap-készítés a Dinnyési Fertőn [Making nest base at the Dinnyés Fertő]. – Madártávlat 6(2): 4. (in Hungarian)

Gabriel, P. O. & Black, J. M. 2012. Correlates and consequences of the pair bond in Steller's Jays. – Ethology 119(2): 178–187. DOI: 10.1111/eth.12051

Greenlaw, J. S. 1977. Taxonomic distribution, origin, and evolution of bilateral scratching in ground-feeding birds. – The Condor 79(4): 426–439. DOI: 10.2307/1367722

Griggio, M. & Hoi, H. 2011. An experiment on the function of the long-term pair bond period in the socially monogamous Bearded Reedling. – Animal Behaviour 82(6): 1329–1335. DOI: 10.1016/j.anbehav.2011.09.016

Griggio, M., Hoi, H., Lukasch, B. & Pilastro, A. 2016. Context-dependent female preference for multiple ornaments in the Bearded Reedling. – Ecology and Evolution 6(2): 493–501. DOI: 10.1002/ece3.1903

Haraszthy, L. 2019. Magyarország fészkelő madarainak költésbiológiája. [Breeding biology of nesting birds of Hungary]. – Pro Vértes Nonprofit Zrt, Csákvár

Henry, P-Y., Poulin, B., Rousset, F., Renaud, F. & Thomas, F. 2004. Infestation by the mite *Harpirhynchus nidulans* in the Bearded Tit *Panurus biarmicus*: Capsule Mites sometimes induced voluminous subcutaneous cysts in featherless parts. – Bird Study 51(1): 34–40. DOI: 10.1080/00063650409461330

Hoi, H. 1997. Assessment of the quality of copulation partners in the monogamous Bearded Tit. – Animal Behaviour 53(2): 277–286. DOI: 10.1006/anbe.1996.0401

Hoi, H., Darolová, A. & Krištofík, J. 2010. Conspecific brood parasitism and anti-parasite strategies in relation to breeding density in female Bearded Tits. – Behaviour 147(12): 1533–1549. DOI: 10.1163/000579510X511060

Hoi, H. & Griggio, M. 2008. Dual utility of a melanin-based ornament in Bearded Tits. – Ethology 114(11): 1094–1100. DOI: 10.1111/j.1439-0310.2008.01566.x

Hoi, H. & Griggio, M. 2011. Is female mate preference based on the interaction between static and dynamic signals in Bearded Reedlings? – Ethology Ecolology & Evolution 23(2): 171–178. DOI: 10.1080/03949370.2011.554879

Hoi, H., Griggio, M. 2012. Bearded Reedlings adjust their pair-bond behaviour in relation to the sex and attractiveness of unpaired conspecifics. – PLoS ONE 7(2): e32806. DOI: 10.1371/journal.pone.0032806

Hoi, H. & Hoi, C. 2001. Habitat selection and habitat use of the Bearded Tit *(Panurus biarmicus)*. – In: Hoi, H. (ed.) The Ecology of Reed Birds. – Austrian Academy of Sciences, Austria, pp. 73–85.

Hoi, H. & Hoi-Leitner, M. 1997. An alternative route to coloniality in the Bearded Tit: females pursue extra-pair fertilisations. – Behaviour Ecology 8(2): 113–119. DOI: 10.1093/beheco/8.2.113

Hořák, D., Procházka, P., Cepák, J. & Zárybnick, J. 2003. Tahové poměry sýkořic vousatých *(Panurus biarmicus)* na území České republiky a Slovenska [Movements of Bearded Tits *(Panurus biarmicus)* in the Czech Republic and Slovakia]. – Sylvia 39: 79–94. (in Czech with English Summary)

Houwen, P. J. 1967. Het voorkomen van het Baardmannetje, *Panurus biarmicus* L. in België tot in het najaar 1966. [Occurrence of the Bearded Reedling, *Panurus biarmicus* L. in Belgium until autumn 1966]. – Le Gerfaut 57(2): 210–219. (in Dutch)

Ječmenica, B. 2016. Novo gnjezdilište Brkate Sjenice Panurus biarmicus u Hrvatskoj [New breeding site of the Bearded Parrotbill Panurus biarmicus in Croatia]. – Larus, 51, 81. (in Croatian with English summary)

Jobling, J. A. 2010. The Helm Dictionary of Scientific Bird Names. – London, Christopher Helm

Gyurácz, L., Bank, L. & Orbán, L. 1997. Populációdinamikai vizsgálatok a barkóscinege *(Panurus biarmicus)* egy dél-magyarországi populációján [Studies on the population dynamics of a Bearded Tit *(Panurus biarmicus)* population in Southern Hungary]. – Aquila 103–104: 67–72.

Keve, G., Csörgő, T., Benke, A., Huber, A., Mórocz, A., Németh, Á., Kalocsa, B., Tamás, E. A, Gyurácz, J., Kiss, O., Kováts, D., Sándor, A. D., Karcza, Zs. & Hornok, S. 2023. Ornithological and molecular evidence of a reproducing *Hyalomma rufipes* population under continental climate in Europe. – Frontiers in Veterinary Science DOI: 10.3389/fvets.2023.1147186

Koenig, O. 1951. Das Aktionssystem der Bartmeise (*Panurus biarmicus* L.) [The behavioral repertoire of the Bearded Tit]. – Österreichische Zoologische Zeitschrift 3: 1–82, 247–325. (in German)

Koshelev, D. V., & Cherkasov, V. A. 2019. Первая регистрация усатой синицы Panurus biarmicus в Тверской области. [The first observation of the bearded reedling Panurus biarmicus in the Tver region] – Russian Ornithological Journal, 28(1852), 5456–5459. (in Russian)

Kovács, G. 1981. Madártelepítési kísérletek a Hortobágyi Nemzeti Parkban [Experiments on establishing breeding sites for birds in the Hortobágy National Park]. – Madártani Tájékoztató 2: 67–70. (in Hungarian)

Krištofík, J., Mašán, P. & Šustek, Z. 2007. Arthropods (Pseudoscorpionidea, Acarina, Coleoptera, Siphonaptera) in nests of the Bearded Tit *(Panurus biarmicus)*. – Biologia (Bratisl.) 62(6): 749–755. DOI: 10.2478/s11756-007-0142-0

Lendvai, Á. Z., Tóth, Z., Mahr, K., Osváth, G., Vogel-Kindgen, S. & Gander, B. A. 2021. Effects of experimental increase in insulin-like growth factor 1 on feather growth rate, moult intensity and feather quality in a passerine bird. – Journal of Experimental Biology 224(14): jeb242481. DOI: 10.1242/jeb.242481

Lendvai, Á. Z., Tóth, Z., Mahr, K., Pénzes, J., Vogel-Kindgen, S., Gander, B. A. & Vágási, C. I. 2023. IGF-1 induces sex-specific oxidative damage and mortalit. – Manuscript in review

Literák, I., Chytil, J., Trnka, A., Fain, A. & Tukač, V. 2005. Subalar cutaneous cysts with *Harpirhynchus nidulans* in bearded tits and hawfinches in Central Europe. – Avian Pathology 34(1): 26–28. DOI: 10.1080/03079450400025422

Lodjak, J. & Verhulst, S. 2020. Insulin-like growth factor 1 of wild vertebrates in a life-history context. – Molecular and Cellular Endocrinology 518: 110978. DOI: 10.1016/j.mce.2020.110978

Lovász, L., Fenyvesi, L. & Gyurácz, J. 2017. Contribution to the study of pair formation strategy of the Bearded Reedling *(Panurus biarmicus)*. – North-West Journal of Zoology 13(2): 297–302.

Mahr, K., Anzengruber, M., Hellerschmid, A., Slezacek, J., Hoi, H., Subbiahdoss, G., Gabor, F. & Lendvai, Á. Z. 2023a Biocompatible polymeric microparticles serve as novel and reliable vehicles for exogenous hormone manipulations in passerines. – General and Comparative Endocrinology 336: 114234. DOI: 10.1016/j.ygcen.2023.114234

Mahr, K., Slezacek, J., Anzengruber, M., Hellerschmid, A., Hoi, H., Gabor, F. & Lendvai, Á. Z. 2023b IGF-1 accelerates ornament expression in a songbird. – Manuscript in preparation

Mahr, K., Vincze, O., Tóth, Z., Hoi, H. & Lendvai, Á. Z. 2020. Insulin-like growth factor 1 is related to the expression of plumage traits in a passerine species. – Behavioral Ecology and Sociobiology 74(3): 39. DOI: 10.1007/s00265-020-2821-6

Malzer, I. 2017. Patterns in the space use of the Bearded Reedling, *Panurus biarmicus*, on the Tay Reedbeds, Scotland. – PhD Thesis, University of Glasgow

Malzer, I. & Hansell, M. 2017. Nest timing, nest site selection and nest structure in a high latitude population of Bearded Reedlings *Panurus biarmicus*. – Bird Study 64(1): 51–61. DOI: 10.1080/00063657.2016.1271771

Malzer, I. & Helm, B. 2015. The seasonal dynamics of artificial nest predation rates along edges in a mosaic managed reed-bed. – PLoS ONE 10(10): e0140247. DOI: 10.1371/journal.pone.0140247

Malzer, I. & West, R. 2015. The Bearded Tit in the UK: conservation and management issues. – British Birds 108: 747–753.

Marin, G., Marchesini, M., Tiloca, G. & Pagano, A. 1994. DNA fingerprinting fails to reveal inbreeding in a small, closed population of Bearded Tits (*Panurus biarmicus* L.). – Ethology Ecology & Evolution 6(2): 243–248. DOI: 10.1080/08927014.1994.9522998

Massi, A. & Spina, F. 1996. Wing moult of the Bearded Reedling *(Panurus biarmicus)* in Northern Italy. – Vogelwarte 38: 180–187.

Mogyorósi, S. 2009. Barkóscinege [Bearded Reedling]. – In: Csörgő, T., Karcza, Zs., Magyar, G., Gyurácz, J., Szép., T., Bankovics, A., Schmidt, A. & Schmidt, E. (eds.) Magyar madárvonulási atlasz [Hungarian Bird Migration Atlas]. – Kossuth Kiadó, Budapest, pp. 539–541. (in Hungarian).

Nagy, G. G. 2021. Barkóscinege (*Panurus biarmicus*, Linnaeus, 1758). [Bearded Reedling]. – In: Szép, T., Csörgő, T., Halmos, G., Lovászi, P., Nagy, K. & Schmidt, A. (eds.) Magyarország madáratlasza [Bird Atlas of Hungary]. – Agrárminisztérium, Magyar Madártani és Természetvédelmi Egyesület, Budapest, pp. 505–507. (in Hungarian with English Summary)

Nielsen, B. 1993. Age dependent variation in wing length of Bearded Tits *Panurus biarmicus*. – Ornis Svecica 3(3): 117–124. DOI: 10.34080/os.v3.23036

Nilsson, E., Taubert, H., Hellgren, O., Huang, X., Palinauskas, V., Markovets, M. Y., Valkiūnas, G. & Bensch, S. 2016. Multiple cryptic species of sympatric generalists within the avian blood parasite *Haemoproteus majoris*. – Journal of Evolution Biology 29(9): 1812–1826. DOI: 10.1111/jeb.12911

O'Sullivan, J. M. O. 1976. Bearded Tits in Britain and Ireland, 1966–74. – British Birds 59: 513–543.

Pearson, D. J. 1975. Moult and its relation to eruptive activity in the Bearded Reedling. – Bird Study 22(4): 205–227. DOI: 10.1080/00063657509476466

Peiró, I. G. 2011. Sex-ratio variation in the Bearded Tit *Panurus biarmicus* in El Hondo Natural Park (SE Iberia). – Revista Catalana D'Ornitologia 27: 40–44.

Peiró, I. G. 2013. Movements, sex-ratios, recovery rates and longevity of the Bearded Reedling *Panurus biarmicus* in Iberia. – Ringing and Migration 28(1): 50–52. DOI: 10.1080/03078698.2013.810855

Peiró, I. G. 2017. The behavioural ecology, local population dynamics and conservation of the Bearded Reedling *Panurus biarmicus* in "El Hondo Natural Park"(SE Spain). – Ecology Evolutionary Biology 2(2): 25–35. DOI: 10.11648/j.eeb.20170202.12

Peiró, I. G. 2020. Water reservoirs dynamics do not affect the abundance and productivity of the Bearded Tit *(Panurus biarmicus)* in "El Hondo Natural Park" (SE Iberia). – International Journal of Avian & Wildlife Biology 5(2): 49–53.

Peiró, I. G. 2021. The size of melanin-based beard ornaments is not related to body condition in the Bearded Reedling. – Revista Catalana d'Ornitologia 37: 42–48. DOI: 10.2436/20.8100.01.32

Peiró, I. G. 2022. The Bearded Tit *Panurus biarmicus* in Iberia. – International Journal of Zoology and Animal Biology 5(6): 1–5. DOI: 10.23880/izab-16000427

Peiró, I. G., Robledano, F. & Esteve, M. A. 2006. The effect of age and sex on wing morphology and body size of the Bearded Tit *Panurus biarmicus* in relation to complete moult. – Ringing and Migration 23(2): 101–106. DOI: 10.1080/03078698.2006.9674352

Poulin, B. & Lefebvre, G. T. 2002. Effect of winter cutting on the passerine breeding assemblage in French Mediterranean reed-beds. – Biodiversity & Conservation 11: 1567–1581.

Regan, J. C., Froy, H., Walling, C. A., Moatt, J. P. & Nussey, D. H. 2020. Dietary restriction and insulin-like signalling pathways as adaptive plasticity: A synthesis and re-evaluation. – Functional Ecology 34(1): 107–128. DOI: 10.1111/1365-2435.13418

Robson, C. 2020. Bearded Reedling – *Panurus biarmicus*. – In: del Hoyo, A., Elliott, J., Sargatal, D., Christie, A. & de Juana, E. (eds.) Birds of the World. – Ithaca: Cornell Lab of Ornithology. DOI: 10.2173/bow.bearee1.01

Romero-Pujante, M., Hoi, H. & Blomqvist, D. 2005. The importance of tail length for habitat use in the Bearded Tit *Panurus biarmicus*: an experimental study. – Ibis 147(3): 464–470. DOI: 10.1111/j.1474-919x.2005.00413.x

Romero-Pujante, M., Hoi, H., Blomqvist, D. & Valera, F. 2002. Tail length and mutual mate choice in Bearded Tits *(Panurus biarmicus)*. – Ethology 108(10): 885–895. DOI: 10.1046/j.1439-0310.2002.00821.x

Sánchez-Macouzet, O., Rodríguez, C. & Drummond, H. 2014. Better stay together: pair bond duration increases individual fitness independent of age-related variation. – Proceedings of the Royal Society B: Biological Society 281(1786). DOI: 10.1098/rspb.2013.2843

Sax, A. & Hoi, H. 1998. Individual and temporal variation in cloacal protuberance size of male Bearded Tits *(Panurus biarmicus)*. – The Auk 115(4): 964–969. DOI: 10.2307/4089514

Sax, A., Hoi, H. & Birkhead, T. R. 1998. Copulation rate and sperm use by female Bearded Tits, *Panurus biarmicus*. – Animal Behaviour 56(5): 1199–1204. DOI: 10.1006/anbe.1998.0859

Saygili, F., Yiğit, N., Çam, P. & Yüce, D. 2013. Morphometric and allozymic differences between Bearded Tit *Panurus biarmicus* (Aves: Passeriformes) subpopulations in a large wetland and a small pond in central Anatolia, Turkey. – Turkish Journal of Zoology 37(2): 149–156. DOI:10.3906/zoo-1207-14

Sluys, R. 1983. Geographical variation and distribution of the Bearded Tit *Panurus biarmicus* (Linnaeus, 1758) (Aves). – Bijdragen tot de Dierkunde 53(1): 13–28.

Solti, B. 2010. A Mátra Múzeum madártani gyűjteménye III. Németh Márton tojásgyűjtemény [The collection of the Mátra Museum III. Németh Márton egg collection]. – Folia Historico Naturalia Musei Matraensis, Supplementum 5: 5–275. (in Hungarian)

Spina, F., Baillie, S. R., Bairlein, F., Fiedler, W. & Thorup, K. (eds.) 2022. The Eurasian African Bird Migration Atlas. – https://migrationatlas.org. EURING/CMS

Spitzer, G. 1972. Jahreszeitliche Aspekte der Biologie der Bartmeise *(Panurus biarmicus)* [Seasonal aspects of the biology of the Bearded Reedling *(Panurus biarmicus)*]. – Journal für Ornithologie 113(3): 241–275. DOI: 10.1007/BF01647507 (in German with English Summary)

Steiner, H. M. 1971. Entwicklung und Mauser der Spinalflur bei der Bartmeise *(Panurus biarmicus)* [Development and moult of the spinal tract in the Bearded Reedling *(Panurus biarmicus)*]. – Journal für Ornithologie 112(1): 36–42. DOI: 10.1007/BF01644078 (in German with English Summary)

Stępniewski, J. 2003. Reuse of old nests by Bearded Reedlings *Panurus biarmicus* in Sweden. – Vogelwelt 124(4): 207–207.

Stępniewski, J. 2012. Biologia lęgowa wąsatki *Panurus biarmicus* na Jeziorze \Loniewskim w latach 1987–2009. [Breeding biology of the Bearded Tit *Panurus biarmicus* at Lake Łoniewskie in the years 1987–2009]. – Ornis Polonica 53: 233–248. (in Polish with English Summary)

Stępniewski, J. & Halupka, L. 2018. Overlapping breeding attempts in the Bearded Tit *(Panurus biarmicus)*. – Avian Researche 9(1): 22. DOI:10.1186/s40657-018-0115-8

Surmacki, A. 2003. Use of playback in estimating numbers of Bearded Tit *Panurus biarmicus* outside the breeding season. – Ornis Hungarica 12–13: 1–2.

Surmacki, A. & Stępniewski, J. 2003. A survey of the Bearded Tit *Panurus biarmicus* during the non-breeding season in a landscape of Western Poland. – Acta Ornithologica 38(1): 53–58.

Surmacki, A., Stępniewski, J. & Stępniewska, M. 2015. Juvenile sexual dimorphism, dichromatism and condition-dependent signaling in a bird species with early pair bonds. – Journal of Ornithology 156(1): 65–73. DOI: 10.1007/s10336-014-1108-y.

Surmacki, A., Stępniewski, J. & Zduniak, P. 2003. Repeatability of egg dimensions within the clutches of Bearded Tit *Panurus biarmicus*. – Acta Ornithologica 38(2): 123–127. DOI: 10.3161/068.038.0209

Surmacki, A. & Stępniewski, J. 2007. Do weather conditions affect the dynamics of Bearded Tit *Panurus biarmicus* populations throughout the year? A case study from western Poland. – Annales Zoologici Fennici 44(1): 35–42.

Szöllősi, E., Tóth, Z., Mahr, K., Hoi, H. & Lendvai, Á. Z. 2020. Extremely low malaria prevalence in a wetland specialist passerine. – Parasitology 147(1): 87–95. DOI: 10.1017/S0031182019001215

Tahon, J., de Mevius, E. & le Hardy, F. 1968. Cinéraires des marais *(Senecio congestus)* et mésanges à moustaches *(Panurus biarmicus)*: deux exemples de dispersion à longue distance à partir d'un vaste foyer temporaire de multiplication [Marsh ragwort *(Senecio congestus)* and Bearded Tits *(Panurus biarmicus)*: Two examples of long-distance dispersal from a large temporary breeding site]. – Aves 5: 164–170.

Tóth, Z., Baldan, D., Albert, C., Hoi, H. & Griggio, M. 2015. Effect of ornament manipulations on following relations in male Bearded Reedlings. – Ethology Ecology & Evolution 28(2): 175–187. DOI: 10.1080/03949370.2015.1030782

Tóth, Z., Mahr, K., Ölveczki, G., Őri, L. & Lendvai, Á. Z. 2022. Food restriction reveals individual differences in insulin-like growth factor-1 reaction norms. – Frontiers in Ecology and Evolution 10: 826968. DOI: 10.3389/fevo.2022.826968

Tóth, Z., Ouyang, J. Q. & Lendvai, Á. Z. 2018. Exploring the mechanistic link between corticosterone and insulin-like growth factor-1 in a wild passerine bird. – PeerJ. 6: e5936. DOI: 10.7717/peerj.5936

Trnka, A. & Prokop, P. 2006. Reed-bed structure and habitat preference of reed passerines during the post-breeding period. – Biologia 61(2): 225–230. DOI: 10.2478/s11756-006-0034-8

Trnka, A., Samaš, P. & Mąkol, J. 2023. Chigger mite (Acariformes: Trombiculidae) infestation in reed passerine birds in Central Europe: a case of the Bearded Tit *Panurus biarmicus*. – Parasitology 150(2): 212–220. DOI: 10.1017/S0031182022001731

Trnka, A., Szinai, P. & Hošek, V. 2006. Daytime activity of reed passerine birds based on mist-netting. – Acta Zoologica Academiae Scientiarum Hungaricae 52: 417–425.

Ueda, K. 1985. Juvenile female breeding of the Fan-tailed Warbler *Cisticola juncidis*: occurrence of two generations in the year. – Ibis 127(1): 111–116. DOI: 10.1111/j.1474-919X.1985.tb05041.x

Vadász, Cs., Mogyorósi, S., Pellinger, A., Aleksza, R. & Biró, Cs. 2011. Results of the breeding passerine census carried out at the Hungarian part of Lake Fertő in 2008. – Ornis Hungarica 19: 11–20.

Vadász, Cs., Németh, Á., Biró, Cs. & Csörgő, T. 2008. The effect of reed cutting on the abundance and diversity of breeding passerines. – Acta Zoologica Academiae Scientiarum Hungaricae 54(Suppl 1): 177–188.

Vágási, C. I. & Tökölyi, J. 2005. A vedlés hatása a tollatkák (Astigmata) menekülési és kolonizációs viselkedésére a barkós cinegéknél *(Panurus biarmicus)* [The effect of moulting on escape and colonization behaviour of feather mites (Astigmata) in Bearded Reedlings *(Panurus biarmicus)*]. – Collegium Biologicum 5: 86–99. (in Hungarian with English Summary).

Voous, K. H. 1962. Die Vogelwelt Europas Und Ihre Verbreitung [Birds of Europe and their distribution]. – Berlin – Hamburg, Verlag Paul Parey (in German)

Vönöcky Schenk, J. 1942. A barkós cinege állománya Dinnyésen. / Der Bartmeisenbestand (Panurus biarmicus russicus Brehm) von Dinnyés. [The population of Bearded Reedling in Dinnyés.] – Aquila 46–49: 459–460, 490–491. (in Hungarian and German)

Wawrzyniak, H. & Sohns, G. 1986. Die Bartmeise *Panurus biarmicus*. 1st ed. [The Bearded Reedling]. – Wittenberg Lutherstadt: Spektrum Akademischer Verlag (in German)

Wilson, J. 1993. Colonisation by Bearded Tits of Leighton Moss, Lancashire. – British Birds 86(8): 352–358.

Wilson, J. 2005. Nest box provision to provide additional nesting sites for Bearded Tits *Panurus biarmicus* at Leighton Moss RSPB Reserve, Lancashire, England. – Conservation Evidence 2: 30–32.

Wilson, J. 2014. The gritting behaviour of Bearded Tits *Panurus biarmicus*. – Ringing and Migration 29(1): 37–40. DOI: 10.1080/03078698.2013.869910

Wilson, J. 2015. A nest-box and colour-ringing study of Bearded Tits *Panurus biarmicus* at Leighton Moss, Lancashire. – Ringing and Migration 30(2): 75–80. DOI: 10.1080/03078698.2015.1128247

Wilson, J. & Hartley, I. R. 2007. Changes in eye colour of juvenile Bearded Tits *Panurus biarmicus* and its use in determining breeding productivity. – Ibis 149(2): 407–411. DOI: 10.1111/j.1474-919X.2006.00630.x

Wilson, J. & Peach, W. 2006. Impact of an exceptional winter flood on the population dynamics of Bearded Tits *(Panurus biarmicus)*. – Animal Conservation 9(4): 463–473. DOI: 10.1111/j.1469-1795.2006.00063.x

Yeung, C. K. L., Lin, R-C., Lei, F., Robson, C., Hung, L. M., Liang, W., Zhou, F., Han, L., Li, S-H. & Yang, X. 2011. Beyond a morphological paradox: Complicated phylogenetic relationships of the parrotbills (Paradoxornithidae, Aves). – Molecular Phylogenetics and Evolution 61(1): 192–202. DOI: 10.1016/j.ympev.2011.06.004

Ornis Hungarica 2023. 31(1): 24–47.
DOI: 10.2478/orhu-2023-0002

Species composition and habitat associations of birds around Jhilmila Lake at Western Chure Landscape, Nepal

Dipendra ADHIKARI[1,2], Jagan Nath ADHIKARI[3,4,9*], Janak Raj KHATIWADA[5,6], Bishnu Prasad BHATTARAI[3,9*], Subarna GHIMIRE[7] & Deepak RIJAL[8]

Received: January 30, 2023 – Revised: March 30, 2023 – Accepted: April 11, 2023

Adhikari, D., Adhikari, J. N., Khatiwada, J. R., Bhattarai, B. P., Ghimire, S. & Rijal, D. 2023. Species composition and habitat associations of birds around Jhilmila Lake at Western Chure Landscape, Nepal. – Ornis Hungarica 31(1): 24–47. DOI: 10.2478/orhu-2023-0002

Abstract Wetlands support around 27% of birds in Nepal, however, there is a paucity of information about bird diversity and the wetland habitat of Western Chure Landscape Nepal. The "point count" method along transects was carried out to evaluate the species composition and habitat associations of birds. A total of 2,532 individuals representing 152 species (winter: N = 140 and summer: N = 91) from 19 orders and 51 families were reported from Jhilmila Lake and its surrounding area. The number of birds was reported to be significantly higher during winter than in the summer season. The species diversity was also higher in winter (Shannon's index (H) = 4.38, Fisher's alpha = 30.67) than in summer (H = 4.21, Fisher's alpha = 34.69) as this area is surrounded by old-growth forest that provides available habitats for forest, grassland- and wetland-dwelling birds. This lake is an example of a wetland present in the Chure area that plays an important role in the conservation of biodiversity along with birds. Hence, we recommend its detailed study in terms of biodiversity and water quality.

Keywords: Chure, bird diversity, endangered, forest, wetland

Összefoglalás A vizes élőhelyek a nepáli madarak körülbelül 27%-át tartják fenn. A nepáli Western Chure Landscape területének fajdiverzitásáról és a vizes élőhelyéről kevés információ áll rendelkezésre. A madarak fajösszetételének és élőhelytársulásainak értékelésére a „pontszámlálás" módszert a transzektek mentén végeztük. A Jhilmila-tóról és környékéről összesen 19 rendbe, 51 családba és 152 fajba (télen: 140, nyáron: 91) tartozó 2532 példányt jelentettek. A madarak száma szignifikánsan magasabb volt télen, mint nyáron (t = 4,17, P = 0,0004). A fajdiverzitás is télen magasabb volt (Shannon index H = 4,38, 4,27 és 4,37 között mozog, Fisher alfa = 30,67), mint nyáron (H = 4,21, 4,12 és 4,23 között mozog, Fisher alfa = 34,69). A területet öreg erdők veszik körül, amelyek élőhelyet biztosítanak az erdő-, gyep- és vizes élőhelytől függő madarak számára. Ez fontos szerepet játszik a biológiai sokféleség, valamint a nyugat-nepáli Chure területe madárvilágának megőrzésében, ezért javasoljuk a biológiai sokféleség további részletes tanulmányozását.

Kulcsszavak: Chure, madár diverzitás, veszélyeztetett, erdő, vizes élőhely

[1] Nepal Conservation and Research Center, Chitwan, Nepal
[2] Small Mammals Conservation and Research Foundation, Kathmandu, Nepal
[3] Central Department of Zoology, Institute of Science and Technology, Tribhuvan University, Kathmandu, Nepal
[4] Department of Zoology, Birendra Multiple Campus, Chitwan, Nepal
[5] Chengdu Institute of Biology, Chinese Academy of Sciences, Chengdu 610041, China
[6] Department of Biology, Lake head University, 955 Oliver Road, Thunder Bay, ON, P7B 5E1, Canada
[7] USAID Program for Aquatic Natural Resource Improvement, Paani Program, Baluwatar, 977-1 4442296, Kathmandu, Nepal
[8] Wildlife Research and education network, Kathmandu, Nepal
[9] Nepal Zoological Society, Kirtipur, Kathmandu, Nepal
** corresponding authors, e-mail: bishnu.bhattarai@cdz.tu.edu.np, jagan.adhikari@bimc.tu.edu.np*

Introduction

Wetlands are highly productive and dynamic ecosystems of the earth and serve as the kidneys of the landscape, biological supermarket, and climate stabilizer (Basnet *et al.* 2016). Wetlands are beneficiary components of biodiversity for the productive ecosystems that are responsible for the sustainability of human and other ecological systems (Pal *et al.* 2021). Wetlands are vulnerable around the world. In fact, wetlands are often viewed as wastelands but these are ecologically important that provide the feeding and breeding ground for wildlife (Bhandari 1998). Western Nepal is famous for its wetland resources (Khatiwada *et al.* 2021). However, there are very few wetlands in the Chure region except some oxbow lakes and dry floodplain areas. The major lakes found in the Chure region of far western Nepal are Betkot, Jhilmila and Mudka (Khatiwada *et al.* 2021).

Nepal harbors 891 species of birds which is 8.87% of the total global bird species (BCN & DNPWC 2016, BCN 2022). Among the reported species, more than 19% of the birds (n = 167) are nationally threatened whereas 42 species are globally threatened and 37 are globally near threatened (BCN & DNPWC 2016, Inskipp *et al.* 2016). NPWC act 1973 listed nine birds (Himalayan Monal *Lophophorus impejanus*, Cheer Pheasant *Catreus wallichii*, Satyr Tragopan *Tragopan satyra*, Bengal Florican *Houbaropsis bengalensis*, Lesser Florican *Sypheotides indicus*, Great Hornbill *Buceros bicornis*, Sarus Crane *Grus antigone*, Black Stork *Ciconia nigra* and White Stork *Ciconia ciconia*) as protected birds (DNPWC 2020). Among nationally threatened birds, 27% of the birds are wetland dependent following 53% forest birds, 15% grassland and open area birds (BCN & DNPWC 2016).

The Chure region extends east to west covering about 12.8% area of Nepal. It is the youngest and most fragile mountain with a unique biodiversity. The Chure region mostly remained forested till the 1950s, but with the human population increment, deforestation in the Chure forest is occurring at an unprecedented rate (Subedi *et al*. 2021). The majority (76%) of the forest areas of the Chure region fall outside the protected areas. Chure provides a habitat for various rare and globally threatened species (Subedi *et al*. 2021). Altogether, 99 species of herpetofauna (24 species of amphibians and 75 species of reptiles), 378 species of birds, and 41 species of mammals, were recorded from the Chure region (Subedi *et al*. 2021).

Habitat selection is one of the major drivers of species distribution which lead to an increase in faunal diversity and provides breeding and feeding opportunities (Kim *et al.* 2018, Iswandaru *et al.* 2020). Forest, wetlands, grassland, agricultural land, human settlements, and open areas are major habitats found in western Nepal (Basnet *et al.* 2016, Grimmett *et al.* 2016, Baral & Inskipp 2020). Birds are the bio-indicators that signify the health and quality of the ecosystem (Bregman *et al.* 2014). Anthropogenic activities such as livestock pressure, human pressure, and unscientific agrochemical practices are the major factors that determine birds' diversity and compositions (Bregman *et al.* 2014). Seasonality is an important factor that affects the diversity and distribution of birds (Adhikari *et al.* 2019). The effects of seasonal changes can affect the abiotic and biotic components of that region. The altitude, aspect, habitat heterogeneity, and course of river changes are the major governing factors that affect the feeding and breeding ground of the birds (Basnet *et al.*

2016, Grimmett *et al.* 2016). These factors ultimately affect the distribution and diversity of the birds. The knowledge of the seasonal abundance of the birds for their habitats is crucial for bird conservation and management.

Majority of the studies have been concentrated on the wetlands of international importance such as Ramsar sites in Nepal (Kafle 2005, Chhetry 2006, Giri & Chalise 2008, Adhikari *et al.* 2018, Adhikari *et al.* 2019). The biodiversity of the wetlands outside the protected areas is less explored. Thus, numerous wetlands with, their biodiversity are being undermined, which makes them more vulnerable to degradation. It is suspected that several of them may get dried up before being documented and such a situation is more acute in the backwaters such as in the wetlands of Chure (Baral & Inskipp 2020). This study is intended to provide detailed information on species composition and habitat associations of birds around Jhilmila Lake, one of the holy and unique lakes at Chure region of Kanchnapur district, western Nepal.

Materials and Methods

Study area

The study was carried out around Jhilimila Lake (a wetland of the Western Chure Landscape) in Bhimdatta Municipality, Kanchanpur district covering an area of 8.5 ha. The area is located in the Middle Western part of the Chure region, South-west of far western Nepal at 29.067° N, 80.188° E, elevation 985 m asl *(Figure 1)*. The lake is surrounded by dense forest with a maximum depth of 11 m (Neupane *et al.* 2010). The average maximum temperature is 30.5 °C during June and July and the average minimum temperature is 17.5 °C during December with an annual 1,422.7 mm/year (DoF 2017). There is a relatively protected Sal Forest around Jhilmila Lake *(Figure 2)*.

Sal *(Shorea robusta)* is the most dominant and canopy-forming tree species. Other associated species include Sindure; Kamala amotto *(Mallotus philipensis)*, Kadam *(Adina cordifolia)*, Saaj; Lourel tree *(Terminalia alata)*, Jamun: Black plum *(Syzygium cumini)*, Bot Dhaiyanro; Small Flowered Crape Myrtle *(Lagerstroemia parviflora)* and Kusum; Honey tree *(Schleichera oleosa)*. Common shrub species include Rudilo; heart-leaf adina *(Pogostemon bengalensis)* and Damai fal *(Ardisia solanacea)*. Bijay Sal; Indian Kino tree *(Pterocarpus marsupium),* a protected species listed in the near threatened category in IUCN Red List.

This area provides shelter for various mammal species such as Spotted Deer *(Axis axis),* Wild Boar *(Sus scrofa)*, Jungle Cat *(Felis chaus)*, Northern Palm Squirrel *(Funambulus pennanti)*, Blue Bull *(Boselaphus tragocamelus)*, Bengal Fox *(Vulpes bengalensis)*, Leopard Cat *(Felis bengalensis)*, Rhesus Macaque *(Macaca mulatta)*, Terai Grey Langur *(Semnopithecus hector)* (Khatiwada *et al.* 2021). More than 100 species of birds have been reported (DoF 2017). Similarly, this area harbors fish species that include Grass Carp *(Cetanoharyngodon idella)*, Bighead Carp *(Hypophthalmichthys nobilis)*, Rohu *(Labeo rohita)*, Mangur *(Clarias batrachus)*, Black Carp *(Mylopharyngodon piceus)*, Silver Carp *(Hypophthalmichthys*

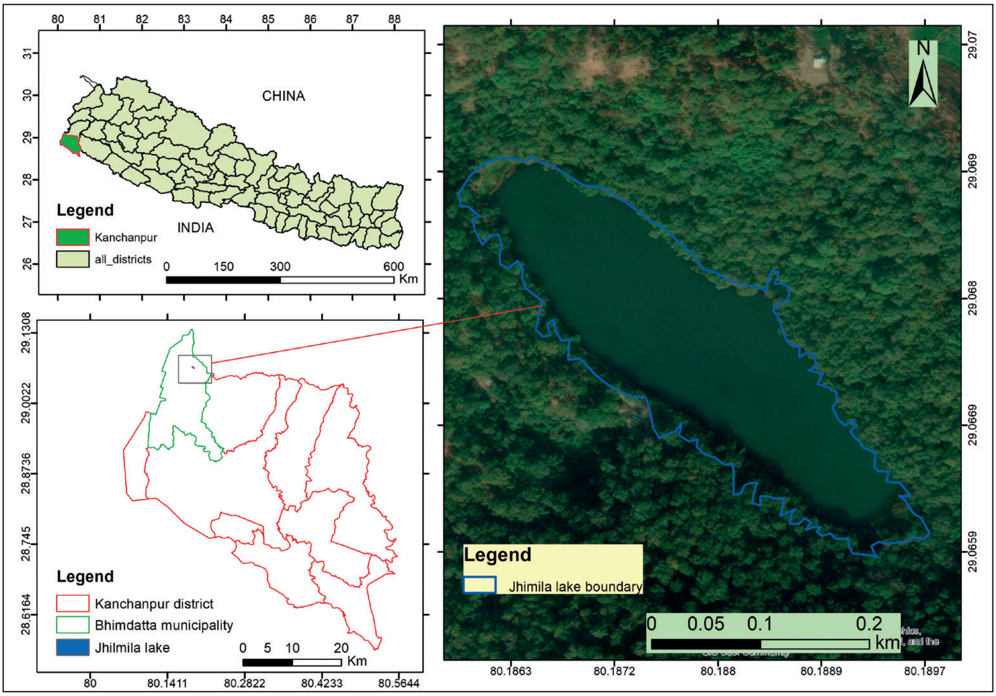


Figure 1. Map showing the study area and location of Jhilmila Lake at Western Chure Landscape, Nepal
1. ábra A Jhilmila-tó és a vizsgálati terület elhelyezkedése a Western Chure Területen, Nepálban

Figure 2. A glimpse of Jhilmila Lake at Western Chure Landscape, Nepal
2. ábra Egy pillantás a Jhilmila-tóra

molitrix). Herpetofauna includes Black-spined Toad *(Bufo melanostictus)*, Common Garden Lizard *(Calotes versicolor)*, Jerdon's Bull Frog *(Haplobatrachus crassus)*, Common Tree Frog *(Polypedates maculates)*, Marbled Cascade Frog *(Amolops marmoratus)*, Black Monitor Lizard *(Varanus bengalensis)*, North Indian Flapshell Turtle *(Lissemys punctata andersoni)*, Asiatic Rock Python *(Python morulus)*, Rat Snake *(Ptyas mucosa)* (DoF 2017).

Bird Survey

A bird survey was carried out following the "point count" method along transects near the bank of the lake and on the way from Jhilmila-wetland following detailed instructions provided by Bibby *et al.* (2000). A total of five transects were laid that ranged from 1.5 km to 2.5 km. In each transect, a minimum of 5 vantage points at each 500 m distance were established and scanned with binoculars (Nikon 8×42) to count the birds. At each point, bird species were counted for five minutes within the 50 m circular diameter by two observers. All the observed species were recorded with abundance by visual and auditory aids along with habitat types and environmental variables *(Table 1)* around the lake. The bird species were identified using the field guidebook for birds of Nepal (Grimmett *et al.* 2016).

The study was carried out for two seasons (summer and winter) of 2019–2020 at 6.00–10.00 and 16:00–18:00 by two observers. We also recorded the sound by using the sound recorder device (Sony E-018/022) of the birds which were not visible but singing that was identified by using the bird song database of Xeno-Canto (https://www.xeno-canto.org/). The zoological name, family, order and conservation status were identified with the help of the IUCN Red List (https://www.iucnredlist.org/) and the Status of Nepal's Birds: The National Red List Series Birds of Nepal (https://www.himalayannature.org/page/red-data-birds).

Table 1. The variables and parameters recorded during field study
1. táblázat A vizsgálat során rögzített változók és paraméterek

SN	Variables	Descriptions
1	Species variables	All the bird species reported in the field.
2	Habitat variables	Types of habitats depend upon the dominant species and condition of the sampling points. The birds were categorized as forest birds, grassland or open-area birds, wetland or wetland dependent birds and shrub or bush birds.
3	Conservation status	IUCN category of threatened status Threatened status as National Redlist data book
4	Migratory status	Residential and winter migratory birds and summer migratory birds
5	Feeding guilds	carnivores, herbivores, omnivores, frugivores, picivores, insectivores, nectivores and granivores
6	Environmental variables	Distance to road (RV), Distance to village or settlements (DV), Distance to water resources (DW), Number of livestock present (Nliv), number of fruiting trees present (NFT), Elevation (Ele)

The feeding guilds of the birds were categorized based on the major food habit. The birds were categorized into eight groups as carnivores, herbivores, omnivores, frugivores, piscivores, insectivores, nectivores and granivores (Grimmett *et al.* 2016). The habitats were categorized based on the dominant species present there. The distances from the village or settlements, roads, and water resources were measured as Euclidean distance from sampling using ArcGIS 10.7. Other variables such as the number of livestock, number of people present, and number of fruiting plants present were reported in each sampling point through direct observations *(Table 1)*.

Data analysis

The data were analyzed by using different statistical tools. A diversity index is a quantitative measure that reflects the composition of the community. These diversity indices are the measurement of biodiversity in different aspects such as richness, evenness and dominance (Morris *et al*. 2014). We used the Shannon-Wiener diversity index (*H*), Simpson index (1-D) and Evenness (e) were calculated as seasons. The significant test of seasonal abundance was examined by using a t-test at 95% confidence level.

A quantitative analysis known as a species discovery curve determines the minimum sampling size required to determine the number of species that represent a community (Willott 2001). This is a widely recognized methodology that is used by the study of Adhikari *et al.* (2019), La Sorte and Somveille (2020). To show whether the sampling effort was sufficient or not, we plotted the species discovery curve. The number of sampling points were placed on the X-axis and cumulative species on the Y-axis (Willott 2001).

Ecologists can visualize relative species abundance which is one of the main biodiversity components, using a rank abundance curve (RAC) or Whittaker plot (Izsák & Pavoine 2012, Avolio *et al.* 2019). This RAC aids in visualizing species richness and evenness (Yin *et al.* 2018). We used (RAC) or Whittaker plot to show the relative abundance of the birds., For this, the species were ranked as 1, 2, 3……based on the abundance of the birds from highest to lower. On plotting, the rank was placed on the X-axis and the relative abundance on the Y-axis (Izsák & Pavoine 2012, Avolio *et al.* 2019).

We used the Detrended Correspondence Analysis (DCA) of species to judge the appropriate test (Correa-Metrio *et al.* 2014) to test the relation of birds of different feeding guilds with habitat types. DCA found more than 4 gradient lengths (gradient length = 4.05). Hence, we selected Canonical Correspondence Analysis (CCA) to measure the associations of the species with habitat using CANOCO v. 4.56 (Ter Braak & Šmilauer 2009). The data are presented in the form of a biplot (Macfaden & Capen 2002). CCA helps to compare a complex relationship between feeding guilds and the habitat. For analyses, we applied a Monte-Carlo permutation test (using 499 unrestricted permutations) to identify the habitats that are significantly associated with the variation in the distribution of birds. During the analysis, we merged the herbivores, nectarivores and frugivores as herbivores feeding guilds because the numbers of species in these categories were low.

Generalized Linear Model (GLM) was used to show the relationship between the species richness and different predictors. The package «pscl» was used in R software version 4.0.0 (R

Core Team 2020) for GLM (Jackman 2020) with 'Poisson identity link function' to calculate coefficient, standard error, and P-value at 95% confidence level for all relationships between species richness and different variables such as distance to water resources (DW), distance to settlement (DS), distance to road (DR), number of fruiting plants *(Table 1)*.

Results

Bird species composition

A total of 2,532 individuals belonging to 19 orders, 51 families and 152 species (winter = 140 species, summer = 98 species) were recorded in our study *(Figure 3, Appendix 1)*. The most abundant species in the winter season belonged to Passeriformes (46.42%), followed by Piciformes (9.28%), Accipitriformes (6.42%) and Coraciiformes (5.71%). In the summer season, Passeriformes (53.06%) were the most abundant followed by Piciformes (9.18%), Coraciiformes (8.16%) and Cuculiformes (7.14%) respectively *(Figure 3)*. Among them, Jungle Babbler (3.64%) were the most abundant species in Jhilmila Lake followed by Common Peafowl (3.43%), Dusky Warbler (3.33%), and House Swift (3.0%) *(Appendix 1)*.

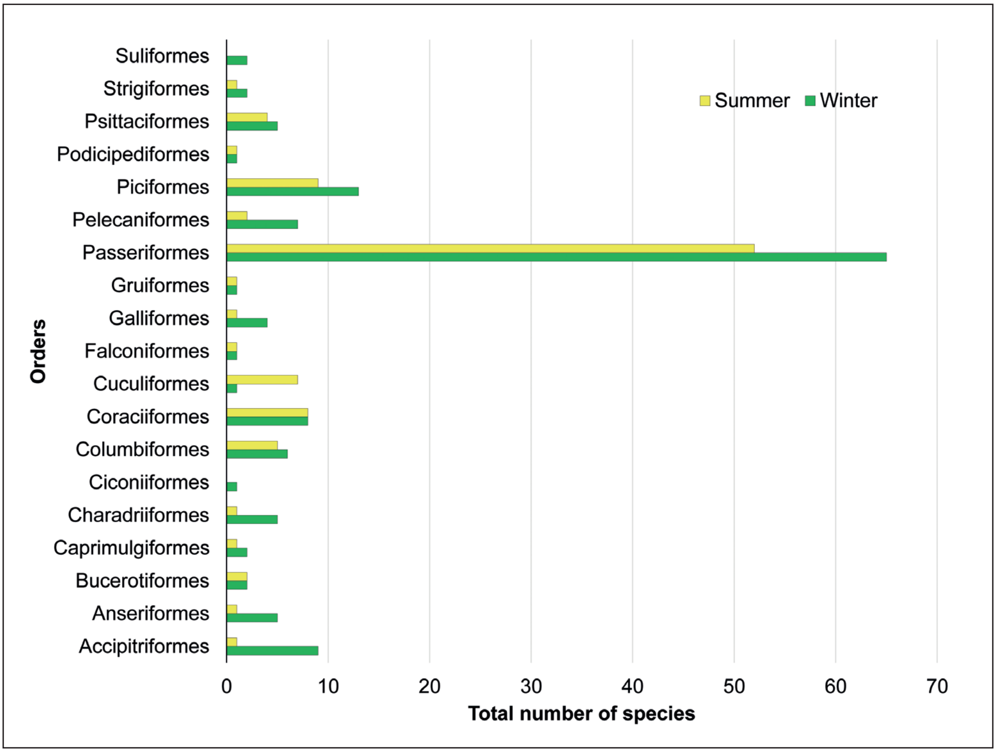


Figure 3. Bird species composition according to their taxonomic order in Jhilmila Lake area of Western Chure Landscape, Nepal

3. ábra Madárfajok összetétele taxonómiai sorrendjük szerint

Jhilmila Lake provides a habitat for 17.15% of the total bird species recorded from Nepal (N = 891). This study reported one globally critically endangered (White-rumped Vulture), one endangered (Egyptian Vulture), three vulnerable (Common Pochard, Great Slaty Woodpecker and Great Hornbill), and four globally near threatened birds (Alexandrine Parakeet, Dark-throated Oriole, Himalayan Griffon, and Asian Woollynecked). Among the reported birds, eight were also listed nationally threatened category (one critically endangered (White-rumped Vulture), two endangered (Great Slaty Woodpecker and Great Hornbill), two vulnerable (Himalayan Griffon and Egyptian Vulture), and three near threatened (Alexandrine Parakeet, Common Pochard and Asian Woollynecked) *(Figure 4, 5)*. This influences the conservation value of Jhilmila Lake.

The species richness of the birds was significantly higher in the winter season (t = 2.17, P = 0.02). The species diversity was higher in winter (Shannon index H = 4.72) than in summer (H = 4.38). There was no difference in the Simpson index of diversity during the winter and summer seasons (Simpson Dominance Index D = 0.01 in winter and D = 0.01 in summer season). The species evenness of birds (0.82) was higher in summer than in winter (evenness = 0.79) *(Table 2)*. The species discovery curve based on the cumulative number of species present in the sampling points showed linear trends and a greater number of species were reported with increasing the number of sampling points *(Figure 6)*.

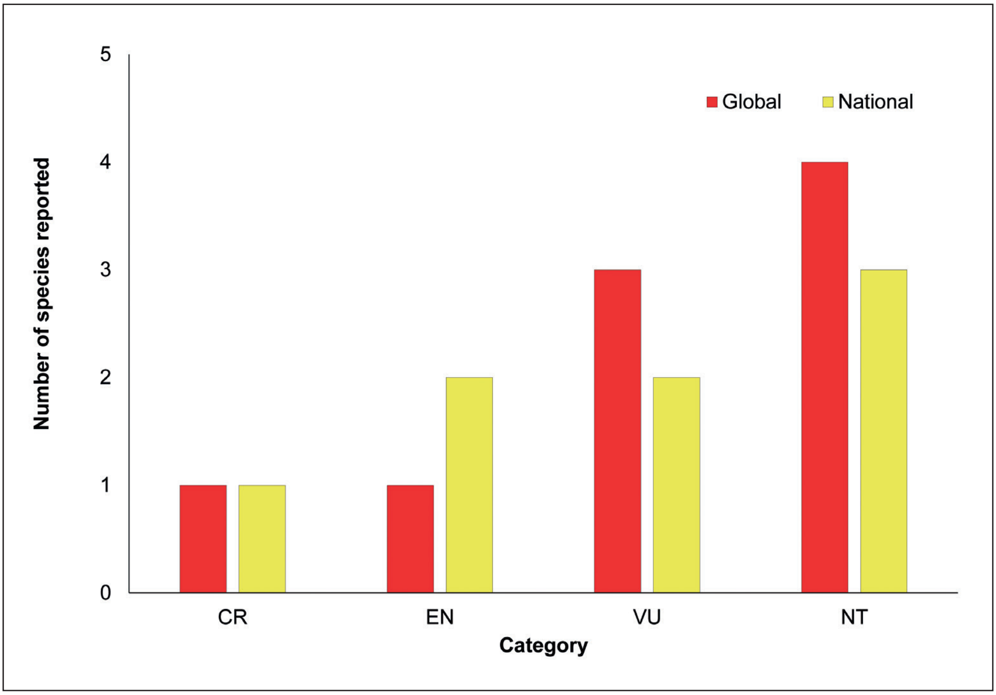


Figure 4. Globally and nationally threatened categories of the birds reported around Jhilmila Lake, here, CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened (NT)

4. ábra A Jhilmila-tó környékén jelentett madarak globálisan és országosan veszélyeztetett kategóriái, itt, CR – kritikusan veszélyeztetett, EN – veszélyeztetett, VU – sebezhető, NT – közel fenyegetett (NT)

Figure 5. Some globally and nationally threatened birds reported around Jhimila Lake, a. White-rumped Vulture *(Gyps bengalensis)*, category: globally and nationally Critically Endangered (CR), b. Egyptian Vulture *(Neophron percnopterus)*, globally Endangered (EN) but nationally Vulnerable (VU), c. Himalayan Griffon *(Gyps himalayensis)*, globally near threatened (NT) and nationally VU, d. Asian Woollynecked *(Ciconia episcopus)*, globally and nationally NT

5. ábra Néhány globálisan és országosan veszélyeztetett madárról számoltak be a Jhimila-tó környékén, a. bengáli keselyű *(Gyps bengalensis)*, kategória: globálisan és országosan kritikusan veszélyeztetett (CR), b. egyiptomi keselyű *(Neophron percnopterus)*, globálisan veszélyeztetett (EN), de országosan sebezhető (VU), c. Himalájai keselyű *(Gyps himalayensis)*, globálisan fenyegetett (NT) és országosan VU, d. ázsiai gyapjasnyakú gólya *(Ciconia episcopus)*, globálisan és nemzeti szinten NT

The species reported from the Jhilmila Lake area (n = 152) were ranked into 14 different categories in summer and 16 different categories in winter depending upon the number of individuals reported. The rank abundance curve (RAC) clearly showed that there were a low number of individuals reported in the case of high-ranking species and a higher relative species abundance in low-ranked species. The relative abundance of the birds in the summer season was relatively higher up to the 10th ranks and formed a steep slope curve after that the relative abundance was low. Comparatively, the species richness of the birds in the winter season was greater than in summer but the relative abundance of ranked species was lower up to ranked 10th after that increased as compared to summer *(Figure 7)*.

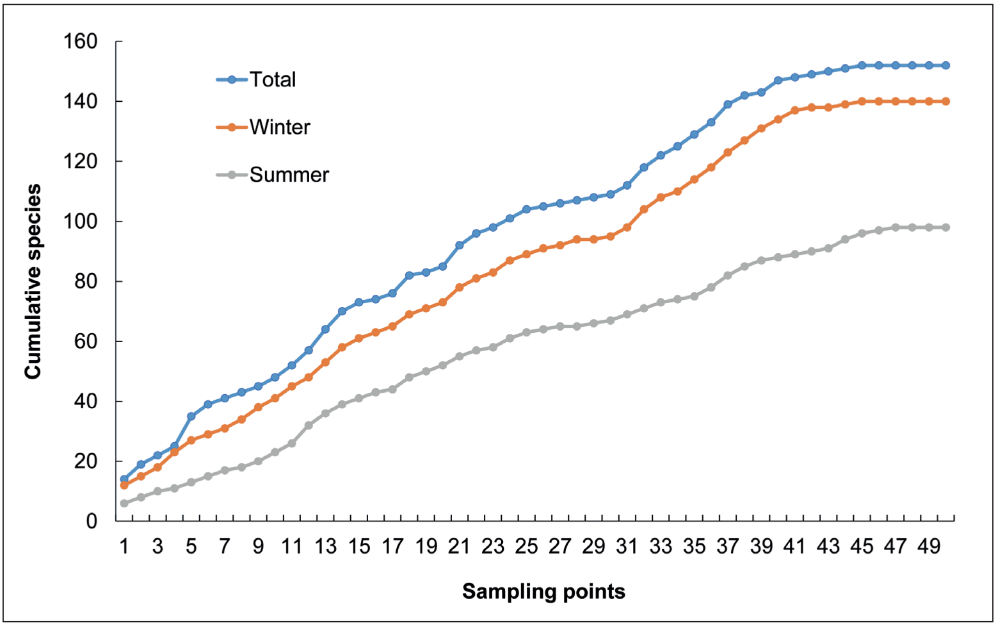


Figure 6. Species discovery curve for birds around Jhilmila Lake
6. ábra A fajok kumulatív görbéje a Jhilmila-tó körüli megfigyelési pontok száma alapján

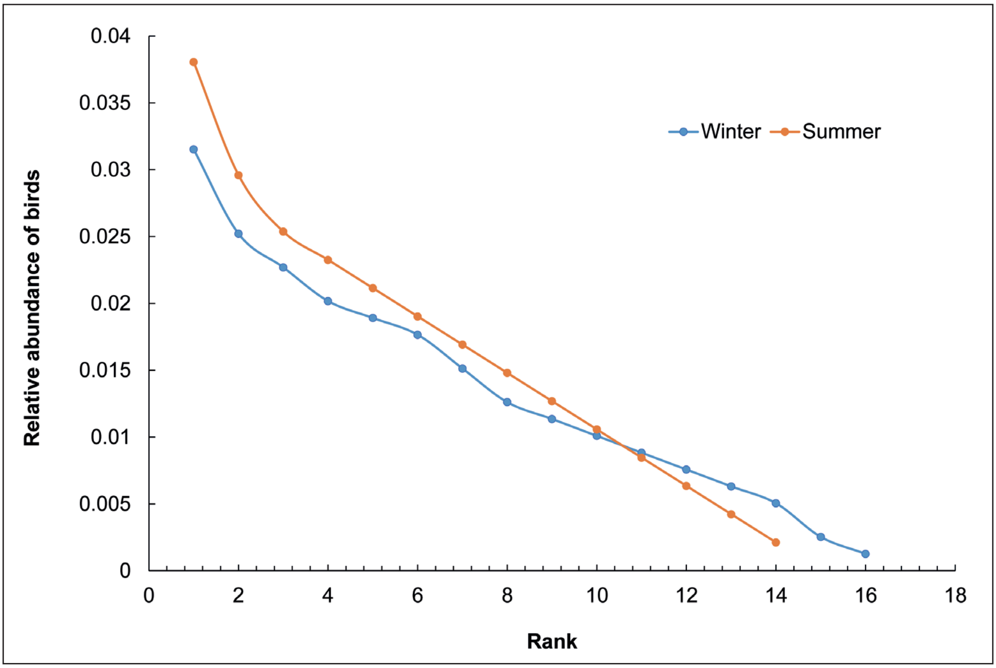


Figure 7. RAC of birds reported around Jhilmila Lake
7. ábra A Jhilmila-tó környéki madarak évszakonkénti relatív abundanciája

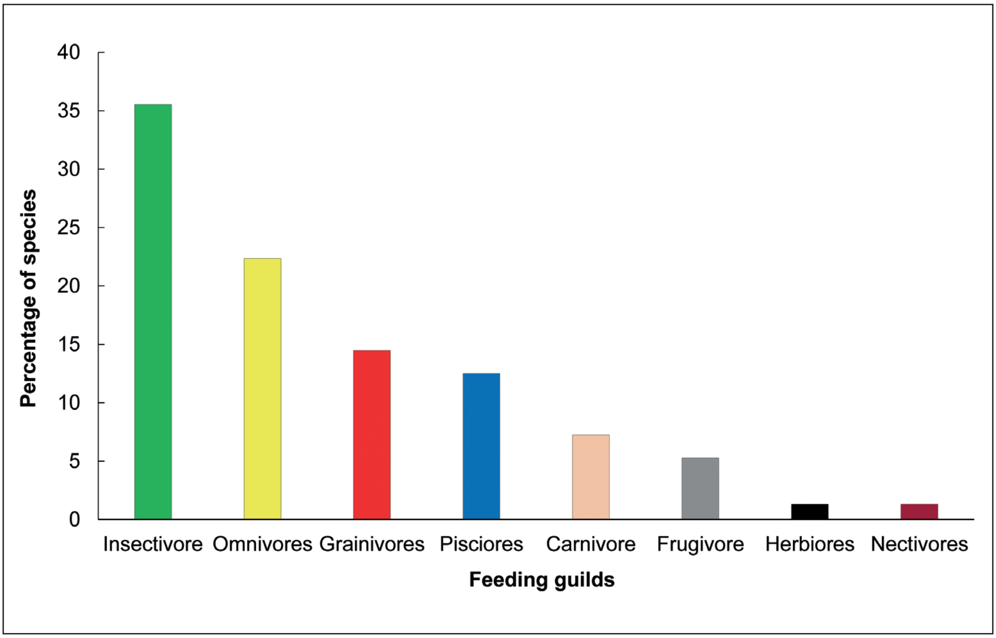


Figure 8. Bird species composition (%) based on their feeding guilds
8. ábra Madárfajok összetétele (%) táplálkozási besorolásuk alapján

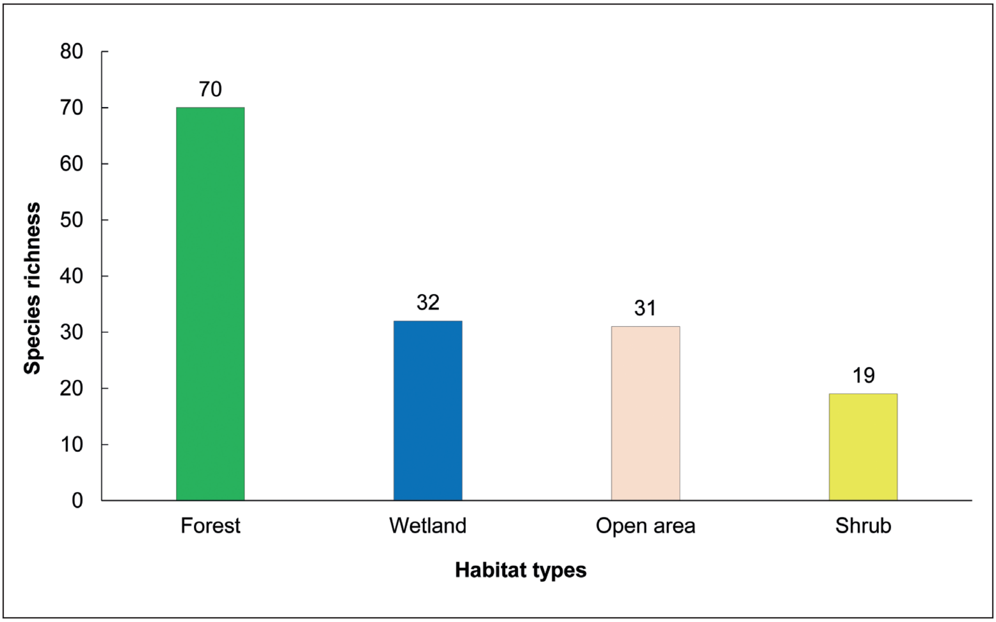


Figure 9. Bird species composition according to their habitat types around Jhilmila Lake
9. ábra Fajgazdagság élőhelytípusok szerint

More than 35% of birds were insectivores followed by omnivores (more than 22%), and granivores (more than 14%), similarly, herbivores and nectivores were the least reported (1.32%) *(Figure 8)*. We reported 70 species of forest birds, 32 species of wetland birds, 31 species of open-area birds, and 19 species of shrub or bush birds *(Figure 9)*.

Habitat associations of birds

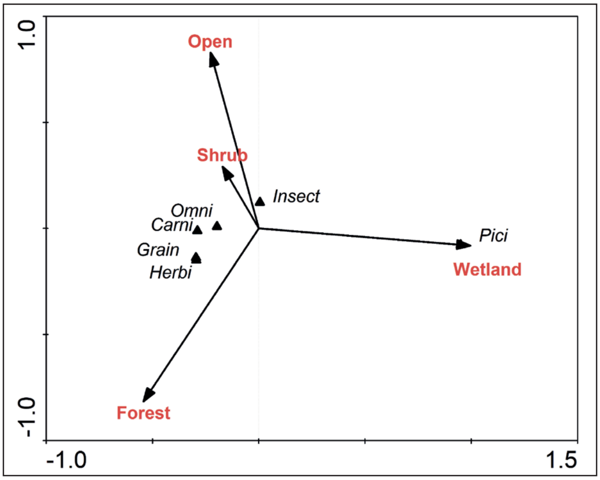


Figure 10. CCA ordination diagram (biplot) showing the bird species association with different habitats types around Jhilmila lake (Here, Open – open area birds, shrub – shrubland birds, Insect – insectivores, Omni – omnivores, Carni – carnivores, Grain – granivores, Herbi – herbivores, Pici – piscivores)

10. ábra CCA ordinációs diagram (biplot), amely a madárfajok társulását mutatja különböző élőhelytípusokkal a Jhilmila-tó körül (Open – nyílt terület, shrub – cserjés madarak, Insect – rovarevők, Omni – mindenevők, Carni – húsevők, Grain – magevők, Herbi – növényevők, Pici – halevők)

The CCA biplot diagram of the Monte-Carlo permutation test of the significance of all canonical axes clearly showed that omnivores, carnivores, granivores, and herbivore birds were significantly higher in the forest, shrub land, and open areas (agriculture fields, residential areas, and grassland) but piscivores birds were reported more in the wetland habitat (F = 1.55, P = 0.002, Trace = 0.91, with 499 permutations) *(Figure 10)*.

Results of GLM showed that species richness was significantly reported nearer to the roads during summer season (z = -2.089, P = 0.036), however, the relation was not significant during winter season (z = -0.952, P = 0.341). The distance to settlements showed a positive, but marginally significant association with the species richness of birds in winter (z = 1.686, P = 0.091) than in summer (z = 1.195, P = 0.23). The distance to water sources, and number of fruiting trees were also showed positive but non-significant relationship with species richness of birds in both seasons *(Table 3)*.

Table 2. Bird species diversity and dominance indices in Jhilmila Lake area at Western Chure Landscape, Nepal

2. táblázat Madárfajok diverzitása és dominancia indexei a Jhilmila-tó területén a Western Chure tájon, Nepálban

	Winter	**Summer**	**Total**
Simpson Dominance_D	0.01	0.01	0.01
Shannon_H	4.72	4.38	4.75
Evenness_e^H/S	0.79	0.82	0.76

Table 3. Generalized Linear Model (GLM) showed the relationship between species richness and different environmental variables in two seasons in Jhilmila Lake area at Western Chure Landscape, Nepal. Here, DR – distance to road, DS – distance to settlements, DW – distance to water sources

3. táblázat Az általánosított lineáris modellek eredményei, amelyek a fajgazdagság és különböző környezeti változók összefüggéseit mutatják két évszakban, a nepáli Nyugat-Chure régió Jhilmila tavánál meghatározott értékek alapján. DR – úttól mért távolság, DS – településtől mért távolság, DW – vízforrástól mért távolság

Summer				
Parameter	**Estimate**	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	6.618	3.0704	2.155	0.031
DR	-0.003	0.002	-2.089	0.036
DS	0.001	0.001	1.195	0.23
DW	0.0003	0.002	0.202	0.83
No of fruiting trees	0.059	0.196	0.303	0.76

Winter				
Parameter	**Estimate**	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	6.506	3.414	1.906	0.05
DR	-0.002	0.002	-0.952	0.341
DS	0.002	0.001	1.686	0.091
DW	0.0006	0.002	0.362	0.717
No of fruiting trees	0.036	0.212	0.168	0.866

Discussion

This study assessed the diversity of birds in and around the Jhimila Lake located on the Chure hill of far western Nepal. Our findings indicate that the community structure of the birds such as species richness, abundance, and feeding habit in and around the lake proved this wetland and the associated forest is biologically significant and provide the breeding and feeding ground for the birds.

Bird species composition

Our study found the highest species richness and species diversity during winter seasons than summer seasons due to more winter migratory birds. This area supported a relatively high species diversity of avian fauna which could be attributed to different habitat types around the lake. This lake is unique and located in the Western Chure Landscape providing foraging and breeding opportunities for wetland and wetland-dependent birds. Higher species richness in the winter season than summer season has been reported in the various studies that were done in the various lakes of Terai regions, e.g. Beeshazari Lake (Adhikari *et al.* 2018), a Ramsar site, Sati Karnali Lake, Kailali, Nepal and Raani Lake, Shuklaphanta National Park, Nepal (Adhikari *et al.* 2022) in. We found more than 46% of Passeriformes birds during winter and more than 53% during summer seasons, i.e. the abundance of Passeriformes was the highest and Ciconiiformes was the lowest as order Passeriformes was represented by a larger number of families and species (Grimmett *et al.* 2016). Passeriformes birds usually forage in large groups and prefer to stay close to agricultural fields and open areas where they found more food grains. Jhilmila Lake and its associated area alone contributed more than 17% of the bird species of Nepal, which showed the importance of this lake and associated areas for biodiversity conservation. Furthermore, this area harbored nine globally threatened bird species (one critically endangered, one endangered, three vulnerable, and four near threatened) among the 43 globally threatened birds (Inskipp *et al.* 2017, BCN 2022).

The species discovery curve for Jhilmila Lake areas indicated the suitable sampling effort for the birds. Our study used RAC to indicate the relation between relative abundance and rank abundance of birds in Jhilmila Lake areas.

Habitat associations of birds

Habitat use by the birds depends upon their feeding guilds. Habitat heterogeneity of the Jhilmila Lake area supported 152 species of birds. Comparatively, insectivore birds were reported more followed by omnivores, granivores, and piscivores birds. The wetland habitat, forest, grassland and open area supported different types of insects that increased the occurrence of insectivore birds (Adhikari *et al.* 2022). The forest around the Jhilmila Lake supported a large number of forest birds (n = 70) and the Jhilmila Lake alone supported 32 species of wetland birds. Our result indicated that this lake of the Chure range of Kanchanpur district provides the feeding and breeding ground to wetland birds. The report of wetland birds from Jhilmila Lake was less than the report of Adhikari *et al.* (2018) from Beeshazari Lake (n = 44), a Ramsar site in Nepal; the report of Lamsal *et al.* (2014) from Ghodaghodi Lake (n = 41), a Ramsar site but comparatively, the area of Jhilmila Lake is lower than these lakes as this lake is comparatively smaller than Beeshhazari and Ghodaghodi lakes. The study revealed that herbivores, granivores, carnivores and omnivore birds were related to the forest and shrubland habitat whereas the open area including grassland supported the insectivores. The number of fruiting trees present in the forest around the Jhilmila Lake area added more food available for the herbivore birds. Similarly, the wetland (lake area) supported the wetland birds. The abundance of the birds is dependent on the food available in that habitat (Kim *et al.* 2018).

The disturbances caused by motorable roads and human activity typically harm bird diversity and abundance (Alexander *et al.* 2019, da Silva & Silva 2020, Leveau & Leveau 2020). Contrarily, in this study, the birds' species richness increased with the decreasing distance to the road during both summer and winter. During these seasons, the movement of the people for worshiping purpose in Jhimila is comparatively more intensive by providing grains nearer the roads which increase the chances of food availability. As it is believed that this lake has a goddess superpower, people from India and Nepal used to visit this lake every month on the full moon during summer. It is believed that the goddess Jhilmila gives strength to fight against problems and brings prosperity to the family. The lake area is surrounded by the forest but the human settlements are not farther than 1 to 2 km. However, the species richness increased by increasing the distance to settlement in both seasons. The farmland surrounding the forest provides a heterogeneous habitat that is utilized by birds (Moges *et al.* 2017, Callaghan *et al.* 2019). The presence of fruit trees also helps to increase the species richness of birds (Pandey *et al.* 2021) but the surrounding area of the lake is dominated by Sal forest and had fewer fruit trees, hence showing a constant relation.

Conclusion

The avian study in and around the Jhilmila Lake pointed out that this lake is ecologically and economically important and harbored 152 species of birds. It plays a vital role in providing breeding, feeding, and shelter to many birds. The surrounding area of this lake is dominated by Sal forest which decreased the number of frugivorous birds. The diversity of birds was comparatively lower in summer than in winter due to winter migratory birds. Variables such as habitat types, distance to water sources, distance to nearer settlements or agricultural lands, and the number of fruiting trees present determined the diversity and species richness of the birds. This holy lake protects the unique biodiversity of Western Chure Landscape but has less priority for conservation. Hence, this study is the baseline for the management and conservation of this important lake and suggested conducting an extensive biodiversity study.

Acknowledgements

The authors would like to thank the Department of Forest and Soil Conservation (DoFSC) for the permission to survey the study area. Similarly, we would like to thank Division Forest Office Kanchanpur for granting permission and support to conduct this research. We express our thanks to USAID-funded Paani Program for supporting this study (G-KAT-041). We are equally thankful to Forest Action Nepal for providing technical support and arranging the field schedule for data collection. We are also thankful to IDEAWILD for field equipment support. Our thanks go to members of Baijanth Community Forest User Group, and local communities of the Matena area for their support in the study area.

References

Adhikari, J. N., Bhattarai, B. P. & Dhakal, D. N. 2018. Conservation value of Beeshhazari Lake: an insight into diversity and abundance of wetland birds. – Our Nature 16(1): 17–26. DOI: 10.3126/on.v16i1.21563

Adhikari, J. N., Bhattarai, B. P. & Thapa, T. B. 2019. Factors affecting diversity and distribution of threatened birds in Chitwan National Park, Nepal. – Journal of Threatened Taxa 11(5): 13511–13522. DOI: 10.11609/jot.4137.11.5.13511-13522

Adhikari, J. N., Khatiwada, J. R., Adhikari, D., Sapkota, S., Bhattarai, B. P., Rijal, D. & Sharma, L. N. 2022. Comparison of bird diversity in protected and non-protected wetlands of western lowland of Nepal. – Journal of Threatened Taxa 14(1): 20371–20386. DOI: 10.3126/on.v16i1.21563

Alexander, J., Smith, D. A. E., Smith, Y. C. E. & Downs, C. T. 2019. Drivers of fine-scale avian functional diversity with changing land use: an assessment of the effects of eco-estate housing development and management. – Landscape Ecology 34: 537–549. DOI: 10.1007/s10980-019-00786-y

Avolio, M. L., Carroll, I. T., Collins, S. L., Houseman, G. R., Hallett, L. M., Isbell, F., Koerner, S. E., Komatsu, K. J., Smith, M. D. & Wilcox, K. R. 2019. A comprehensive approach to analyzing community dynamics using rank abundance curves. – Ecosphere 10(10): e02881. DOI: 10.1002/ecs2.2881

Baral, H. S. & Inskipp, C. 2020. Birds of Nepal: Their Status and Conservation Especially with Regards to Watershed Perspectives. – Hindu Kush-Himalaya Watersheds Downhill: Landscape Ecology and Conservation Perspectives. – Springerpp. 435–458. DOI: 10.1007/978-3-030-36275-1_22

Basnet, T. B., Rokaya, M. B., Bhattarai, B. P. & Münzbergová, Z. 2016. Heterogeneous landscapes on steep slopes at low altitudes as hotspots of bird diversity in a Hilly Region of Nepal in the Central Himalayas. – PLoS One 11:e0150498. DOI: 10.1371/journal.pone.0150498

BCN. 2022. Status of Birds of Nepal. – Bird Conservation Nepal, Kathmandu

BCN & DNPWC. 2016. Birds of Nepal: An Official Checklist. – Bird Conservation Nepal (BCN) and Department of National Parks and Wildlife Conservation (DNPWC), Kathmandu, Nepal

Bhandari, B. 1998. An Inventory of Nepal's Wetlands. Final Report, IUCN Nepal. – Wetlands and Heritage Unit, IUCN Nepal, Kathmandu, Nepal, Kathmandu, Nepal

Bregman, T. P., Sekercioglu, C. H. & Tobias, J. A. 2014. Global patterns and predictors of bird species responses to forest fragmentation: implications for ecosystem function and conservation. – Biological Conservation 169: 372–383. DOI: 10.1016/j.biocon.2013.11.024

Callaghan, C. T., Bino, G., Major, R. E., Martin, J. M., Lyons, M. B. & Kingsford, R. T. 2019. Heterogeneous urban green areas are bird diversity hotspots: insights using continental-scale citizen science data. – Landscape Ecology 34: 1231–1246.

Chhetry, D. 2006. Diversity of wetland birds around the Koshi Barrage area. – Our Nature 4(1): 91–95. DOI: 10.3126/on.v4i1.507

Correa-Metrio, A., Dechnik, Y., Lozano-García, S. & Caballero, M. 2014. Detrended correspondence analysis: A useful tool to quantify ecological changes from fossil data sets. – Boletín de la Sociedad Geológica Mexicana 66(1): 135–143.

da Silva, B. G. & Silva, W. R. 2020. Impacts of park roads and trails on a community of Atlantic Forest fruit-eating birds. – Tropical Ecology 61: 371–386. DOI: 10.1007/s42965-020-00097-3

DNPWC. 2020. Protected birds of Nepal under NPWC Act 1973. – Department of National Parks and Wildlife Conservation (DNPWC)

Giri, B. & Chalise, M. K. 2008. Seasonal diversity and population status of waterbirds in Phewa lake, Pokhara, Nepal. – Journal of Wetlands Ecology 1(1–2): 3–7.

Grimmett, R., Inskipp, C., Inskipp, T. & Baral, H. S. 2016. Birds of Nepal Revised ed. – Bloomsbury Publishing

Inskipp, C., Baral, H. S., Inskipp, T., Khatiwada, A. P., Khatiwada, M. P., Poudyal, L. P. & Amin, R. 2017. Nepal's National red list of birds. – Journal of Threatened Taxa 9(1): 9700–9722. DOI: 10.11609/jott.2855.9.1.9700-9722

Inskipp, C., Baral, H. S., Phuyal, S., Bhatt, T. R., Khatiwada, M., Inskipp, T., Khatiwada, A., Gurung, S., Singh, P. B., Murray, L., Poudyal, L. & Amin, R. 2016. The Status of Nepal's Birds: The National Red List Series. – Zoological Society of London, UK.

Iswandaru, D., Novriyanti, N., Banuwa, I. S. & Harianto, S. P. 2020. The distribution of bird communities in University of Lampung, Indonesia. – Biodiversitas Journal of Biological Diversity 21(6): 2629–2637. DOI: 10.13057/biodiv/d210634

Izsák, J. & Pavoine, S. 2012. Links between the species abundance distribution and the shape of the corresponding rank abundance curve. – Ecological Indicators 14(1): 1–6. DOI: 10.1016/j.ecolind.2011.06.030

Jackman, S. 2020. pscl: Classes and Methods for R Developed in the Political Science Computational Laboratory: United States Studies Centre, University of Sydney, Sydney, New South Wales, Australia. – https://github.com/atahk/pscl/

Kafle, G. 2005. Avifaunal Survey and Vegetation Analysis at Ghodaghodi Lake of Nepal. – A Report Submitted to Oriental Bird Club (OBC), United Kingdom

Khatiwada, J. R., Adhikari, J. N., Rijal, D. & Sharma, L. N. 2021. Freshwater biodiversity in western Nepal: A review. – Nepalese Journal of Zoology 5(1): 34–46. DOI: 10.3126/njz.v5i1.38290

Kim, J-Y., Lee, S., Shin, M-S., Lee, C-H., Seo, C. & Eo, S. H. 2018. Altitudinal patterns in breeding bird species richness and density in relation to climate, habitat heterogeneity, and migration influence in a temperate montane forest (South Korea). – PeerJ 6:e4857. DOI: 10.7717/peerj.4857

La Sorte, F. A. & Somveille, M. 2020. Survey completeness of a global citizen-science database of bird occurrence. – Ecography 43(1): 34–43. DOI: 10.1111/ecog.04632

Lamsal, P., Pant, K. P., Kumar, L. & Atreya, K. 2014. Diversity, uses, and threats in the Ghodaghodi Lake complex, a Ramsar site in western lowland Nepal. – International Scholarly Research Notices 2014: ID 680102. DOI: 10.1155/2014/680102

Leveau, L. M. & Leveau, C. M. 2020. Street design in suburban areas and its impact on bird communities: Considering different diversity facets over the year. – Urban Forestry Urban Greening 48: 126578. DOI: 10.1016/j.ufug.2019.126578

MacFaden, S. W.& Capen, D. E. 2002. Avian habitat relationships at multiple scales in a New England forest. – Forest Science 48(2): 243–253. DOI: 10.1093/forestscience/48.2.243

Moges, E., Masersha, G., Chanie, T., Addisu, A., Mesfin, B. V. E. & Beyen, Ch. W. 2017. Species diversity, habitat association and abundance of avifauna and large mammals in Gonde Teklehimanot and Aresema monasteries in North Gondar, Ethiopia. – International Journal of Biodiversity and Conservation 10(4): 185–191 DOI: 10.5897/IJBC2017.1136

Morris, E. K., Caruso, T., Buscot, F., Fischer, M., Hancock, C., Maier, T. S., Meiners, T., Müller, C., Obermaier, E., Prati, D. & Socher, S. A. 2014. Choosing and using diversity indices: insights for ecological applications from the German Biodiversity Exploratories. – Ecology and Evolution 4(18): 3514–3524. DOI: 10.1002/ece3.1155

Neupane, P. K., Khadka, M., Adhikari, R. & Bhuju, D. R. 2010. Lake water quality and surrounding vegetation in Dry Churiya Hills, Far-Western Nepal. – Nepal Journal of Science and Technology 11: 181–188. DOI: 10.3126/njst.v11i0.4142

Pal, K. B., Bishwakarma, K., Chalaune, T. B., Upadhaya, D., Joshi, T. R., Thapa, L. B., Sharma, M. L., Joshi, S. & Pant, R. R. 2021. Hydrochemical assessment of Jhilmila Lake, Kanchanpur, Nepal. – Scientific World 14(14): 124–131. DOI: 10.3126/sw.v14i14.35023

Pandey, N., Khanal, L., Chapagain, N., Singh, K. D., Bhattarai, B. P. & Chalise, M. K. 2021. Bird community structure as a function of habitat heterogeneity: A case of Mardi Himal, Central Nepal. – Biodiversitas Journal of Biological Diversity 22(1): 262–271. DOI: 10.13057/biodiv/d220132

R Development Core Team 2020. R: A language and environment for statistical computing. – R Foundation for Statistical Computing, Vienna, Austria. R Foundation for Statistical Computing, Vienna, Austria

Subedi, N., Bhattarai, S., Pandey, M. R., Kadariya, R., Thapa, S. K., Gurung, A., Prasai, A., Lamichhane, S., Regmi, R., Dhungana, M., Regmi, P. R., Paudel, R. P., Kumpakha, B., Shrestha, B., Gautam, B., Baral, R., Poudel, U., Yadav, S., Pariyar, S. & Lamichhane, B. R. 2021. Report on Faunal Diversity in Chure Region of Nepal. – President Chure-Terai Madhesh Conservation Development Board and National Trust for Nature Conservation. Kathmandu, Nepal

Ter Braak, C. J. F. & Šmilauer, P. 2009. Canoco for Windows. Biometris-quantitative methods in the life and earth sciences. – Plant Research International, Wageningen University Research Centre, the Netherlands

Willott, S. 2001. Species accumulation curves and the measure of sampling effort. – Journal of Applied Ecology 38(2): 484–486. DOI: 10.1046/j.1365-2664.2001.00589.x

Yin, Z-Y., Zeng, L., Luo, S-M., Chen, P., He, X., Guo, W. & Li, B. 2018. Examining the patterns and dynamics of species abundance distributions in succession of forest communities by model selection. – PLoS One 13:e0196898. DOI: 10.1371/journal.pone.0196898

Appendix1. Bird species composition around Jhilmila Lake with their common name, scientific name, order, family, encounter rate, abundance, IUCN and NRDB threatened status
1. melléklet A madárfajok listája a Jhilmila-tó körül

SN	Common Name	Zoological name	Order	Family	Winter	Summer	Encounter rate	Abundance %	IUCN	NRDB
1	Shikra	*Accipiter badius* (Gmelin, 1788)	Accipitriformes	Accipitridae	2	0	2	0.21	LC	LC
2	Himalayan Buzzard	*Buteo buteo* Portenko, 1929	Accipitriformes	Accipitridae	2	0	2	0.21	LC	LC
3	Black-winged Kite	*Elanus caeruleus* (Desfontaines, 1789)	Accipitriformes	Accipitridae	2	1	3	0.32	LC	LC
4	White-rumped Vulture	*Gyps bengalensis* (Gmelin, 1788)	Accipitriformes	Accipitridae	2	0	2	0.21	CR	CR
5	Himalayan Griffon	*Gyps himalayensis* Hume, 1869	Accipitriformes	Accipitridae	4	0	4	0.43	NT	VU
6	Black Kite	*Milvus migrans* (Boddaert, 1783)	Accipitriformes	Accipitridae	6	0	6	0.64	LC	LC
7	Egyptian Vulture	*Neophron percnopterus* (Linnaeus, 1758)	Accipitriformes	Accipitridae	2	0	2	0.21	EN	VU
8	Crested Serpent Eagle	*Spilornis cheela* (Latham, 1790)	Accipitriformes	Accipitridae	2	0	2	0.21	LC	LC
9	Osprey	*Pandion haliaetus* (Linnaeus, 1758)	Accipitriformes	Pandionidae	2	0	2	0.21	LC	LC
10	Common Teal	*Anas crecca* Linnaeus, 1758	Anseriformes	Anatidae	7	0	7	0.75	LC	LC
11	Mallard	*Anas platyrhynchos* Linnaeus, 1758	Anseriformes	Anatidae	7	0	7	0.75	LC	LC
12	Common Pochard	*Aythya ferina* (Linnaeus, 1758)	Anseriformes	Anatidae	2	0	2	0.21	VU	NT
13	Lesser Whistling-duck	*Dendrocygna javanica* (Horsfield, 1821)	Anseriformes	Anatidae	6	2	8	0.86	LC	LC
14	Gadwall	*Mareca strepera* (Linnaeus, 1758)	Anseriformes	Anatidae	2	0	2	0.21	LC	LC
15	Great Hornbill	*Buceros bicornis* Linnaeus, 1758	Bucerotiformes	Bucerotidae	0	1	1	0.11	VU	EN
16	Indian Grey Hornbill	*Ocyceros birostris* (Scopoli, 1786)	Bucerotiformes	Bucerotidae	4	0	4	0.43	LC	LC
17	Common Hoopoe	*Upupa epops* Linnaeus, 1758	Bucerotiformes	Upupidae	2	2	4	0.43	LC	LC
18	House Swift	*Apus nipalensis* (Hodgson, 1836)	Caprimulgiformes	Apodidae	16	12	28	3.00	LC	LC
19	Alpine Swift	*Tachymarptis melba* (Linnaeus, 1758)	Caprimulgiformes	Apodidae	12	0	12	1.29	LC	LC
20	Grey-headed Lapwing	*Vanellus cinereus* (Blyth, 1842)	Charadriiformes	Charadriidae	2	2	4	0.43	LC	LC
21	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	Charadriiformes	Charadriidae	4	0	4	0.43	LC	LC

SN	Common Name	Zoological name	Order	Family	Winter	Summer	Encounter rate	Abundance %	IUCN	NRDB
22	Bronze-winged Jacana	*Metopidius indicus* (Latham, 1790)	Charadriiformes	Jacanidae	8	0	8	0.86	LC	LC
23	Common Sandpiper	*Actitis hypoleucos* Linnaeus, 1758	Charadriiformes	Scolopacidae	4	0	4	0.43	LC	LC
24	Green Sandpiper	*Tringa ochropus* Linnaeus, 1758	Charadriiformes	Scolopacidae	2	0	2	0.21	LC	LC
25	Asian Woollyneck	*Ciconia episcopus* (Boddaert, 1783)	Ciconiiformes	Ciconiidae	2	0	2	0.21	NT	NT
26	Emerald Dove	*Chalcophaps indica* (Linnaeus, 1758)	Columbiformes	Columbidae	6	2	8	0.86	LC	LC
27	Oriental Turtle-dove	*Streptopelia orientalis* (Latham, 1790)	Columbiformes	Columbidae	4	4	8	0.86	LC	LC
28	Red Collared Dove	*Streptopelia tranquebarica* (Hermann, 1804)	Columbiformes	Columbidae	4	0	4	0.43	LC	LC
29	Rock Dove	*Columba livia* Gmelin, 1789	Columbiformes	Columbidae	12	14	26	2.79	LC	LC
30	Spotted Dove	*Spilopelia chinensis* (Scopoli, 1786)	Columbiformes	Columbidae	4	8	12	1.29	LC	LC
31	Eurasian Collared Dove	*Streptopelia decaocto* Frivaldszky, 1838	Columbiformes	Columbidae	2	4	6	0.64	LC	LC
32	Common Kingfisher	*Alcedo atthis* (Linnaeus, 1758)	Coraciiformes	Alcedinidae	5	4	9	0.97	LC	LC
33	Stork-billed Kingfisher	*Pelargopsis capensis* (Linnaeus, 1766)	Coraciiformes	Alcedinidae	2	0	2	0.21	LC	LC
34	Pied Kingfisher	*Ceryle rudis* (Linnaeus, 1758)	Coraciiformes	Alcedinidae	2	2	4	0.43	LC	LC
35	White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	Coraciiformes	Alcedinidae	9	4	13	1.39	LC	LC
36	Indian Roller	*Coracias benghalensis* (Linnaeus, 1758)	Coraciiformes	Coraciidae	3	3	6	0.64	LC	LC
37	Chestnut-headed Bee-eater	*Merops leschenaulti* Vieillot, 1817	Coraciiformes	Meropidae	4	4	8	0.86	LC	LC
38	Blue-headed Bee-eater	*Merops muelleri* (Cassin, 1857)	Coraciiformes	Meropidae	10	12	22	2.36	LC	LC
39	Asian Green Bee-eater	*Merops orientalis* Latham, 1802	Coraciiformes	Meropidae	18	6	24	2.58	LC	LC
40	Blue-tailed Bee-eater	*Merops philippinus* Linnaeus, 1766	Coraciiformes	Meropidae	0	6	6	0.64	LC	LC
41	Greater Coucal	*Centropus sinensis* (Stephens, 1815)	Cuculiformes	Cuculidae	0	2	2	0.21	LC	LC
42	Indian Cuckoo	*Cuculus micropterus* Gould, 1837	Cuculiformes	Cuculidae	0	4	4	0.43	LC	LC
43	Banded Bay Cuckoo	*Cacomantis sonneratii* (Latham, 1790)	Cuculiformes	Cuculidae	0	6	6	0.64	LC	LC

SN	Common Name	Zoological name	Order	Family	Winter	Summer	Encounter rate	Abundance %	IUCN	NRDB
44	Lesser Coucal	*Centropus bengalensis* (Gmelin, 1788)	Cuculiformes	Cuculidae	0	5	5	0.54	LC	LC
45	Common Cuckoo	*Cuculus canorus* Linnaeus, 1758	Cuculiformes	Cuculidae	0	3	3	0.32	LC	LC
46	Western Koel	*Eudynamys scolopaceus* (Linnaeus, 1758)	Cuculiformes	Cuculidae	0	4	4	0.43	LC	LC
47	Common Hawk-cuckoo	*Hierococcyx varius* (Vahl, 1797)	Cuculiformes	Cuculidae	2	2	4	0.43	LC	LC
48	Common Kestrel	*Falco tinnunculus* Linnaeus, 1758	Falconiformes	Falconidae	2	3	5	0.54	LC	LC
49	Kalij Pheasant	*Lophura leucomelanos* (Latham, 1790)	Galliformes	Phasianidae	2	0	2	0.21	LC	LC
50	Black Francolin	*Francolinus francolinus* (Linnaeus, 1766)	Galliformes	Phasianidae	4	0	4	0.43	LC	LC
51	Red Junglefowl	*Gallus gallus* (Linnaeus, 1758)	Galliformes	Phasianidae	4	0	4	0.43	LC	LC
52	Common Peafowl	*Pavo cristatus* Linnaeus, 1758	Galliformes	Phasianidae	25	7	32	3.43	LC	LC
53	White-breasted waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	Gruiformes	Rallidae	4	5	9	0.97	LC	LC
54	Rufous-winged Lark	*Mirafra assamica* Horsfield, 1840	Passeriformes	Alaudidae	4	2	6	0.64	LC	LC
55	Scarlet Minivet	*Pericrocotus flammeus* (Forster, 1781)	Passeriformes	Campephagidae	4	2	6	0.64	LC	LC
56	Zitting Cisticola	*Cisticola juncidis* (Rafinesque, 1810)	Passeriformes	Cisticolidae	4	0	4	0.43	LC	LC
57	Common Tailorbird	*Orthotomus sutorius* (Pennant, 1769)	Passeriformes	Cisticolidae	4	6	10	1.07	LC	LC
58	Jungle Prinia	*Prinia sylvatica* Jerdon, 1840	Passeriformes	Cisticolidae	5	0	5	0.54	LC	LC
59	Common Green Magpie	*Cissa chinensis* (Boddaert, 1783)	Passeriformes	Corvidae	4	8	12	1.29	LC	LC
60	Red-billed Blue Magpie	*Urocissa erythroryncha* (Boddaert, 1783)	Passeriformes	Corvidae	2	2	4	0.43	LC	LC
61	Jungle Crow	*Corvus levaillantii* Lesson, 1831	Passeriformes	Corvidae	10	11	21	2.25	LC	LC
62	House Crow	*Corvus splendens* Vieillot, 1817	Passeriformes	Corvidae	7	0	7	0.75	LC	LC
63	Grey Treepie	*Dendrocitta formosae* Swinhoe, 1863	Passeriformes	Corvidae	2	2	4	0.43	LC	LC
64	Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)	Passeriformes	Corvidae	4	3	7	0.75	LC	LC
65	Yellow-billed Blue Magpie	*Urocissa flavirostris* (Blyth, 1846)	Passeriformes	Corvidae	4	2	6	0.64	LC	LC
66	Ashy Drongo	*Dicrurus leucophaeus* Vieillot, 1817	Passeriformes	Dicruridae	5	5	10	1.07	LC	LC

SN	Common Name	Zoological name	Order	Family	Winter	Summer	Encounter rate	Abundance %	IUCN	NRDB
67	Black Drongo	*Dicrurus macrocercus* Vieillot, 1817	Passeriformes	Dicruridae	10	11	21	2.25	LC	LC
68	Lesser Racquet-tailed Drongo	*Dicrurus remifer* (Temminck, 1823)	Passeriformes	Dicruridae	4	0	4	0.43	LC	LC
69	Spangled Drongo	*Dicrurus bracteatus* (Gould, 1842)	Passeriformes	Dicruridae	4	0	4	0.43	LC	LC
70	Greater Racquet-tailed Drongo	*Dicrurus paradiseus* (Linnaeus, 1766)	Passeriformes	Dicruridae	6	6	12	1.29	LC	LC
71	White-rumped Munia	*Lonchura striata* (Linnaus, 1766)	Passeriformes	Estrildidae	3	3	6	0.64	LC	LC
72	Barn Swallow	*Hirundo rustica* Linnaeus, 1758	Passeriformes	Hirundinidae	12	10	22	2.36	LC	LC
73	Northern House Martin	*Delichon urbicum* (Linnaeus, 1758)	Passeriformes	Hirundinidae	15	10	25	2.68	LC	LC
74	Wire-tailed Swallow	*Hirundo smithii* Leach, 1818	Passeriformes	Hirundinidae	15	5	20	2.15	LC	LC
75	Brown Shrike	*Lanius cristatus* Linnaeus, 1758	Passeriformes	Laniidae	6	0	6	0.64	LC	LC
76	Long-tailed Shrike	*Lanius schach* Linnaeus, 1758	Passeriformes	Laniidae	12	6	18	1.93	LC	LC
77	Common Babbler	*Argya caudata* (Dumont, 1823)	Passeriformes	Leiotrichidae	4	3	7	0.75	LC	LC
78	Jungle Babbler	*Turdoides striata* (Dumont, 1823)	Passeriformes	Leiotrichidae	16	18	34	3.65	LC	LC
79	White-throated Laughingthrush	*Garrulax albogularis* (Gould, 1836)	Passeriformes	Leiotrichidae	0	9	9	0.97	LC	LC
80	White-crested Laughingthrush	*Garrulax leucolophus* (Hardwicke, 1815)	Passeriformes	Leiotrichidae	6	0	6	0.64	LC	LC
81	Rufous-necked Laughingthrush	*Garrulax ruficollis* (Jardine & Selby, 1838)	Passeriformes	Leiotrichidae	12	8	20	2.15	LC	LC
82	Black-napped Monarch	*Hypothymis azurea* (Boddaert, 1783)	Passeriformes	Monarchidae	4	0	4	0.43	LC	LC
83	Indian Paradise-flycatcher	*Terpsiphone paradisi* (Linnaeus, 1758)	Passeriformes	Monarchidae	0	4	4	0.43	LC	LC
84	White Wagtail	*Motacilla alba* Linnaeus, 1758	Passeriformes	Motacillidae	5	0	5	0.54	LC	LC
85	Gray Wagtail	*Motacilla cinerea* Tunstall, 1771	Passeriformes	Motacillidae	6	8	14	1.50	LC	LC
86	White-browed Wagtail	*Motacilla maderaspatensis* Gmelin, 1789	Passeriformes	Motacillidae	2	2	4	0.43	LC	LC
87	Oriental Magpie-robin	*Copsychus saularis* (Linnaeus, 1758)	Passeriformes	Muscicapidae	5	4	9	0.97	LC	LC
88	Grey Bushchat	*Saxicola ferreus* Gray, 1846	Passeriformes	Muscicapidae	2	2	4	0.43	LC	LC

SN	Common Name	Zoological name	Order	Family	Winter	Summer	Encounter rate	Abundance %	IUCN	NRDB
89	Common Stonechat	*Saxicola torquatus* (Linnaeus, 1766)	Passeriformes	Muscicapidae	10	8	18	1.93	LC	LC
90	Spotted Forktail	*Enicurus maculatus* Vigors, 1831	Passeriformes	Muscicapidae	4	2	6	0.64	LC	LC
91	Blue Whistling Thrush	*Myophonus caeruleus* (Scopoli, 1786)	Passeriformes	Muscicapidae	5	0	5	0.54	LC	LC
92	Small Niltava	*Niltava macgrigoriae* (Burton, 1836)	Passeriformes	Muscicapidae	5	1	6	0.64	LC	LC
93	White-winged Redstart	*Phoenicurus erythrogastrus* (Güldenstädt, 1775)	Passeriformes	Muscicapidae	4	0	4	0.43	LC	LC
94	White-capped Water-redstart	*Phoenicurus leucocephalus* (Vigors, 1831)	Passeriformes	Muscicapidae	5	0	5	0.54	LC	LC
95	Pied Bushchat	*Saxicola caprata* (Linnaeus, 1766)	Passeriformes	Muscicapidae	5	0	5	0.54	LC	LC
96	White-tailed Stonechat	*Saxicola leucurus* (Blyth, 1847)	Passeriformes	Muscicapidae	4	0	4	0.43	LC	LC
97	Indian Robin	*Saxicoloides fulicatus* (Linnaeus, 1766)	Passeriformes	Muscicapidae	2	2	4	0.43	LC	LC
98	Little Spiderhunter	*Arachnothera longirostra* (Latham, 1790)	Passeriformes	Nectariniidae	2	0	2	0.21	LC	LC
99	Crimson Sunbird	*Aethopyga siparaja* (Raffles, 1822)	Passeriformes	Nectariniidae	2	1	3	0.32	LC	LC
100	Indian Golden Oriole	*Oriolus kundoo* Sykes, 1832	Passeriformes	Oriolidae	5	5	10	1.07	LC	LC
101	Dark-throated Oriole	*Oriolus xanthonotus* Horsfield, 1821	Passeriformes	Oriolidae	4	4	8	0.86	NT	LC
102	Black-hooded Oriole	*Oriolus xanthornus* (Linnaeus, 1758)	Passeriformes	Oriolidae	0	4	4	0.43	LC	LC
103	Great Tit	*Parus major* Linnaeus, 1758	Passeriformes	Paridae	2	4	6	0.64	LC	LC
104	Chestnut-shouldered Bush-sparrow	*Gymnoris xanthocollis* (Burton, 1838)	Passeriformes	Passeridae	14	2	16	1.72	LC	LC
105	House Sparrow	*Passer domesticus* (Linnaeus, 1758)	Passeriformes	Passeridae	10	8	18	1.93	LC	LC
106	Yellow-vented Warbler	*Phylloscopus cantator* (Tickell, 1833)	Passeriformes	Phylloscopidae	4	0	4	0.43	LC	LC
107	Dusky Warbler	*Phylloscopus fuscatus* (Blyth, 1842)	Passeriformes	Phylloscopidae	20	11	31	3.33	LC	LC
108	Grey-hooded Warbler	*Phylloscopus xanthoschistos* (Gray, 1846)	Passeriformes	Phylloscopidae	0	1	1	0.11	LC	LC
109	Baya Weaver	*Ploceus philippinus* (Linnaeus, 1766)	Passeriformes	Ploceidae	4	4	8	0.86	LC	LC

SN	Common Name	Zoological name	Order	Family	Winter	Summer	Encounter rate	Abundance %	IUCN	NRDB
110	Black Bulbul	*Hypsipetes leucocephalus* (Gmelin, 1789)	Passeriformes	Pycnonotidae	10	8	18	1.93	LC	LC
111	Himalayan Bulbul	*Pycnonotus leucogenys* (Gray, 1835)	Passeriformes	Pycnonotidae	5	3	8	0.86	LC	LC
112	Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	Passeriformes	Pycnonotidae	6	6	12	1.29	LC	LC
113	Red-whiskered Bulbul	*Pycnonotus jocosus* (Linnaeus, 1758)	Passeriformes	Pycnonotidae	8	6	14	1.50	LC	LC
114	Pale-footed Bush-warbler	*Hemitesia pallidipes* (Blanford, 1872)	Passeriformes	Scotocercidae	2	0	2	0.21	LC	LC
115	Chestnut-bellied Nuthatch	*Sitta cinnamoventris* Blyth, 1842	Passeriformes	Sittidae	8	3	11	1.18	LC	LC
116	Velvet-fronted Nuthatch	*Sitta frontalis* Swainson, 1820	Passeriformes	Sittidae	4	2	6	0.64	LC	LC
117	Jungle Myna	*Acridotheres fuscus* (Wagler, 1827)	Passeriformes	Sturnidae	5	5	10	1.07	LC	LC
118	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	Passeriformes	Sturnidae	10	10	20	2.15	LC	LC
119	Orange-headed Thrush	*Geokichla citrina* (Latham, 1790)	Passeriformes	Turdidae	8	4	12	1.29	LC	LC
120	Bar-winged Flycatcher	*Hemipus picatus* (Sykes, 1832)	Passeriformes	Vangidae	4	6	10	1.07	LC	LC
121	Oriental White-eye	*Zosterops palpebrosus* (Temminck, 1824)	Passeriformes	Zosteropidae	2	2	4	0.43	LC	LC
122	Grey-sided Bush Warbler	*Cettia brunnifrons* (Hodgson, 1845)	Passeriformes	Scotocercidae	12	12	24	2.58	LC	LC
123	Grey Heron	*Ardea cinerea* Linnaeus, 1758	Pelecaniformes	Ardeidae	4	7	11	1.18	LC	LC
124	Intermediate Egret	*Ardea intermedia* Wagler, 1829	Pelecaniformes	Ardeidae	8	0	8	0.86	LC	LC
125	Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	Pelecaniformes	Ardeidae	4	0	4	0.43	LC	LC
126	Great White Egret	*Ardea alba* Linnaeus, 1758	Pelecaniformes	Ardeidae	2	0	2	0.21	LC	LC
127	Grey Heron	*Ardea cinerea* Linnaeus, 1758	Pelecaniformes	Ardeidae	2	0	2	0.21	LC	LC
128	Little Egret	*Egretta garzetta* (Linnaeus, 1766)	Pelecaniformes	Ardeidae	6	0	6	0.64	LC	LC
129	Red-napped Ibis	*Pseudibis papillosa* (Temminck, 1824)	Pelecaniformes	Threskiornithidae	2	5	7	0.75	LC	LC
130	Blue-throated Barbet	*Psilopogon asiaticus* (Latham, 1790)	Piciformes	Megalaimidae	5	2	7	0.75	LC	LC
131	Coppersmith Barbet	*Psilopogon haemacephalus* (Müller, 1776)	Piciformes	Megalaimidae	4	0	4	0.43	LC	LC

SN	Common Name	Zoological name	Order	Family	Winter	Summer	Encounter rate	Abundance %	IUCN	NRDB
132	Great Barbet	*Psilopogon virens* (Boddaert, 1783)	Piciformes	Megalaimidae	2	2	4	0.43	LC	LC
133	Brown-headed Barbet	*Psilopogon zeylanicus* (Gmelin, 1788)	Piciformes	Megalaimidae	4	0	4	0.43	LC	LC
134	Pale-headed Woodpecker	*Gecinulus grantia* (McClelland, 1840)	Piciformes	Picidae	7	3	10	1.07	LC	LC
135	Yellow-crowned Woodpecker	*Leiopicus mahrattensis* (Latham, 1801)	Piciformes	Picidae	5	0	5	0.54	LC	LC
136	Great Slaty Woodpecker	*Mulleripicus pulverulentus* (Temminck, 1826)	Piciformes	Picidae	2	1	3	0.32	VU	EN
137	Grey-capped Woodpecker	*Picoides canicapillus* (Blyth, 1845)	Piciformes	Picidae	4	0	4	0.43	LC	LC
138	Fulvous-breasted Woodpecker	*Dendrocopos macei* (Vieillot, 1818)	Piciformes	Picidae	4	6	10	1.07	LC	LC
139	Grey-headed Woodpecker	*Dendropicos spodocephalus* (Bonaparte, 1850)	Piciformes	Picidae	4	4	8	0.86	LC	LC
140	Rufous Woodpecker	*Micropternus brachyurus* (Vieillot, 1818)	Piciformes	Picidae	7	5	12	1.29	LC	LC
141	Brown-capped Pygmy Woodpecker	*Picoides nanus* (Vigors, 1832)	Piciformes	Picidae	7	3	10	1.07	LC	LC
142	Lesser Yellownape	*Picus chlorolophus* Vieillot, 1818	Piciformes	Picidae	2	4	6	0.64	LC	LC
143	Little Grebe	*Tachybaptus ruficollis* (Pallas, 1764)	Podicipediformes	Podicipedidae	5	2	7	0.75	LC	LC
144	Plum-headed Parakeet	*Psittacula cyanocephala* (Linnaeus, 1766)	Psittaciformes	Psittacidae	10	5	15	1.61	LC	LC
145	Red-breasted Parakeet	*Psittacula alexandri* (Linnaeus, 1758)	Psittaciformes	Psittacidae	15	0	15	1.61	LC	LC
146	Alexandrine Parakeet	*Psittacula eupatria* (Linnaeus, 1766)	Psittaciformes	Psittacidae	4	2	6	0.64	NT	NT
147	Slaty-headed Parakeet	*Psittacula himalayana* (Lesson, 1832)	Psittaciformes	Psittacidae	12	6	18	1.93	LC	LC
148	Rose-ringed Parrakeet	*Psittacula krameri* (Scopoli, 1769)	Psittaciformes	Psittacidae	6	4	10	1.07	LC	LC
149	Jungle Owlet	*Glaucidium radiatum* (Tickell, 1833)	Strigiformes	Strigidae	1	0	1	0.11	LC	LC
150	Asian Barred Owlet	*Glaucidium cuculoides* (Vigors, 1831)	Strigiformes	Strigidae	4	2	6	0.64	LC	LC
151	Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	Suliformes	Phalacrocoracidae	4	0	4	0.43	LC	LC
152	Great Cormorant	*Phalacrocorax carbo* (Linnaeus, 1758)	Suliformes	Phalacrocoracidae	12	0	12	1.29	LC	LC

Ornis Hungarica 2023. 31(1): 48–61.
DOI: 10.2478/orhu-2023-0003

Species composition of bird assemblages on waste landfills in Kharkov Region

Yana Yuriivna DEMENTIEIEVA*, Angela Borysivna CHAPLYGINA &
Roman Ivanovych KRATENKO

Received: January 30, 2023 – Revised: April 11, 2023 – Accepted: April 15, 2023

Dementieieva, Y. Y., Chaplygina, A. B. & Kratenko, R. I. 2023. Species composition of bird assemblages on waste landfills in Kharkov Region. – Ornis Hungarica 31(1): 48–61. DOI: 10.2478/orhu-2023-0003

Abstract The article lists the bird species of solid waste landfills for the period 2019–2022 in the Kharkiv region of Ukraine. A total of 73 species in 56 genera, 27 families and 11 orders were registered at the seven largest landfills in the region. We performed faunal and ecological analyses to determine the structure of the landfills' avifauna by status, relative abundance, distribution by landfill zones, and protection status. We found solid waste landfills to play an important role for birds of various ecological groups, as 53% of species use the territory as a nesting place or permanent habitat. In addition, a significant proportion of registered birds are protected by various regulatory and legal acts of Ukraine and the world, pointing out the importance of landfills for endangered birds. We calculated the Menhinick and Shannon indices to estimate the species richness and abundance, which did not show high species diversity. Therefore, we also calculated the Pielow index to quantify the evenness of the grouping structure. In addition, the Berger-Parker index showed the importance of the dominant species, which negates the uniformity and thus, the stability of the groups. The general characteristics of the formation of the avifauna were revealed by the qualitative and quantitative (Jaccard and Sørenson indices) comparisons of bird habitats in the Kharkiv region and the Autonomous Republic of Crimea. As a result, we drew conclusions about the similar factors of the formation and grouping structure of the specific avifauna, as well as the environmental conditions creating the differences.

Keywords: avifauna, solid waste landfills, transformed urban landscapes, region biodiversity

Összefoglalás Tanulmányunk Ukrajna Harkov régiójában szilárdhulladék-lerakók területén 2019–2022 között megfigyelt madárfajokat mutatja be. A vidék hét legnagyobb hulladéklerakóján 11 rendbe, 27 családba, 56 nemzetségbe tartozó 73 fajt figyeltünk meg. Fauna- és ökológiai elemzésekkel meghatároztuk a hulladéklerakók madárvilágának szerkezetét állapot, fajlagos tömegesség, hulladéklerakó-övezet általi megoszlás és védettségi állapot szerint. Megállapítottuk, hogy a szilárdhulladék-lerakók fontos szerepet töltenek be a különböző ökológiai csoportokba tartozó madarak számára, mivel a fajok 53%-a fészkelőhelyként vagy állandó élőhelyként használja azokat. A megfigyelt madárfajok jelentős részét Ukrajna és a világ különböző szabályozási és jogi dokumentumai védik. Így feltételezhetjük, hogy a hulladéklerakók a veszélyeztetett madarak számára fontos élőhelyek. A fajgazdagság és tömegesség becslésére a Menhinick és Shannon mutatókat használtuk, amelyek nem jeleztek nagy diverzitást. A Pielow indexszel is kiszámítottuk a közösség szerkezetének egyenletességét. A Berger-Parker index egyértelművé tette a domináns fajok jelentőségét, ezáltal tagadva a csoportok egységességét, így állandóságát. A madárfauna általános jellemzőit a Harkiv régió és a Krími Autonóm Köztársaság madár élőhelyeinek minőségi és mennyiségi (Jaccard és Sørenson indexek) összehasonlítása tárta fel. Következtetéseket vontunk le az adott madárfauna kialakulásának és csoportosulási szerkezetének hasonló tényezőire, valamint a különbségeket létrehozó környezeti feltételekre nézve.

Kulcsszavak: madárvilág, szilárdhulladék-lerakók, átalakult városi tájak, vidék élővilágának sokszínűsége

H. S. Skovoroda Kharkiv Pedagogical University, Valentynivska Street, Kharkiv 61168, Ukraine
** corresponding author, e-mail: dementeeva.y@gmail.com*

Introduction

Solid household waste landfills are highly transformed landscapes that create conditions for the formation of a high diversity and high-density avifauna (Dementieieva *et al.* 2021, Dementieieva 2021a). The main factors in the formation of large groups of birds are an unlimited food resource and a large space for resting, nesting, roosting and wintering.

Species diversity is usually formed from large flocks of polyphagous and saprophagous birds, such as Gulls (Belant *et al.* 1993, Meissner & Betleja 2007, Caron-Beaudoin *et al.* 2013, Bárbara *et al.* 2017, O'Hanlon *et al.* 2017), Corvids (Vuorisaloa *et al.* 2003, Marasinghe *et al.* 2018, Noreen & Sultan 2021, Soualah *et al.* 2021), White Storks (Rumbold *et al.* 2009, Arizaga *et al.* 2018, Jagiello *et al.* 2018, Marasinghe *et al.* 2018, Bialas *et al.* 2020, Bialas *et al.* 2021, Dementieieva 2021b, Rao *et al.* 2021), Sparrows, Starlings and Pigeons (Soualah *et al.* 2021), Herons (Burger & Gochfeld 1983, Abigail *et al*. 2013). Landfills are large, relatively human-free territories, rich in insects and seeds of ruderal plants, which attract many native birds (Kostin 2020). The large number of different birds attracts birds of prey to these territories as well (Turrin *et al.* 2015, Carlin 2019), which may eventually change feeding habits and use human food waste or livestock waste.

A large body of information have already been published about birds nesting at landfills around the world: America (Belant *et al.* 1993, Belant 1997, Rumbold *et al.* 2009), Canada (Chen *et al.* 2013), Oman (Mcgrady & Alfazari 2013), Poland (Zduniak *et al.* 2021), Western Europe and Africa (Vuorisaloa *et al.* 2003, Pellissier *et al.* 2012, Jagiello *et al.* 2018, Bialas *et al.* 2020, Bialas *et al.* 2021) and even the Arctic (Saalfeld *et al.* 2013). Bird nutrition and its health consequences have been described in many studies. Thus, a significant role is played by the birds of landfills in the spread of resistance to antimicrobial drugs in the population of nearby towns and villages (Blanco & Bautista 2020, Martín-Maldonado *et al.* 2020, Ruiz-Ripa *et al.* 2020, Anand *et al.* 2021, Jarma *et al.* 2021).

Landfills play a significant role in exposing birds to pollution because they accumulate a wide variety of persistent chemical compounds and their residues (Chen *et al.* 2013). Some pollutants accumulate in the yolk of bird eggs (Tongue 2020). Studies of heavy metal pollution have shown that the levels of metals in the body of White Stork chicks can be influenced by the parents' use of landfills as feeding sites (de la Casa-Resino *et al.* 2014). Birds are also contaminated with microplastics, which can be transferred through trophic chains up to higher-order consumers (Belant *et al.* 1993). There are also higher level of endoparasite infections (Parejo *et al.* 2015), mutilation and injuries in birds (Michalicha & Pitucha 2019) staying at landfills. In general, the listed factors indicate both the significant negative impact of landfills on the ecology of many species of birds, as well as the significant role of landfills in the modern life of many species. On average, the avifauna of landfill sites is represented by more than 50 species of birds. All this indicates the relevance of careful monitoring studies on the species composition of birds of landfills as an indicator, because sharp changes in behavior or numbers will give impetus to the search for the cause. This, in turn, will most likely consist of certain negative environmental aspects: climate change, acid rain, abnormal pressure indicators, pollution with hazardous waste, etc. Birds are among the best indicators because they are easy to observe, and they give quick responses to environmental changes.

Materials and Methods

We studied the avifauna of solid waste landfills in the Kharkiv region between 2019 and 2022. Seven landfills of the region were identified as test sites: Dergachy and Rohan landfills of the city of Kharkiv, as well as Kupyansk, Lozova, Nova Vodolaga, Merefa, and Zmiiv landfills (Dementieieva 2022) *(Figure 1)*. The Dergachy landfill (0.8917 km^2) *(Figure 2b)* is located 15 km north of the city of Kharkiv and 500 meters from the village of Novi Dergachy, in the valley of the Lopan River. The Rogan landfill (0.3662 km^2) *(Figure 2a)* is located on the southern border of the city of Kharkiv in the valley of Studenok River. The Kupyansk landfill (0.1003 km^2) *(Figure 2d)* is situated 4 km southwest of Kupyansk, in the

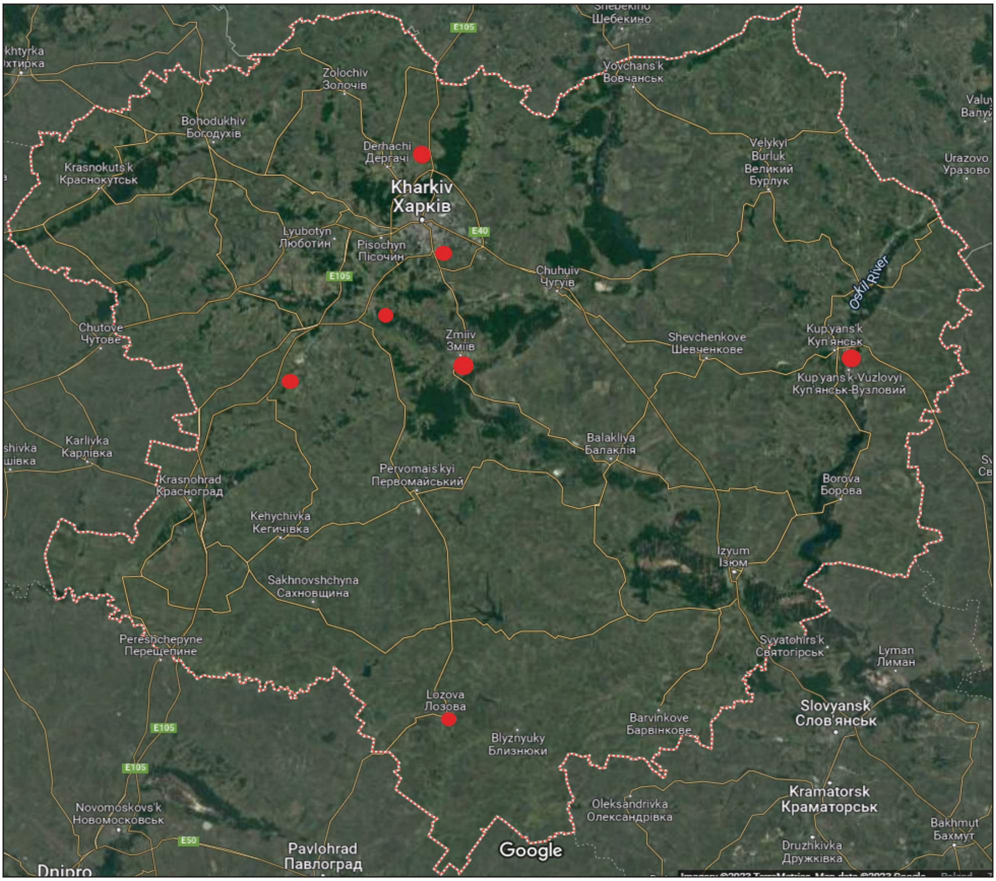


Figure 1. Investigated landfills of Kharkiv region, Ukraine (www.ua-maps.com)
1. ábra Vizsgált hulladéklerakók Ukrajna Harkov régiójában

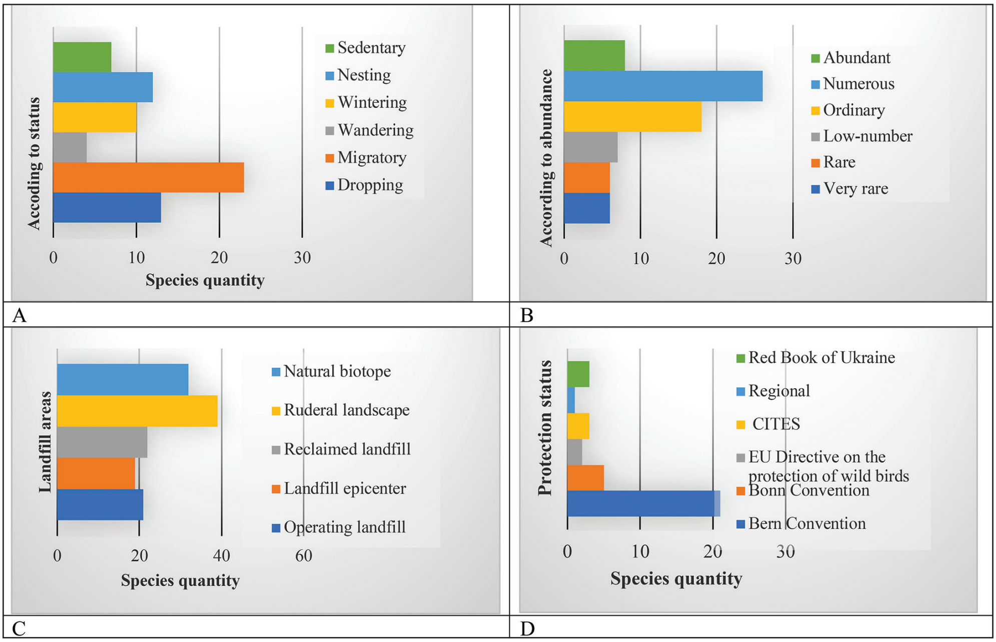


Figure 2. Analysis of landfills in Kharkiv region A: Distribution of species diversity according to status, B: Distribution of species diversity according to abundance degree, C. Distribution by landfill areas, D: Species distribution by protection status

2. ábra Hulladéklerakók elemzése a Harkov-régióban A: A faji sokféleség megoszlása állapot szerint, B: A faji sokféleség megoszlása a tömegesség foka szerint, C: Megoszlás hulladéklerakó-területek szerint, D: Fajmegoszlás védettségi állapot szerint

valley of the Oskil River. The Lozova landfill (0.0614 km^2) *(Figure 2c)* is located 1 km south of the city of Lozova, in the valley of the Gnyla River. The landfill borders the territory of the water treatment facilities of the city of Lozova, which clearly affects the formation of the species composition of birds. Zmiiv landfill (0.0299 km^2) *(Figure 2e)* lies 4 km from the city of Zmiivskyi, in a branch of Siverskyi Donets River (the largest river of the Kharkiv region). The Merefa landfill (0.0322 km^2) *(Figure 2g)* is located in the village of Yakivlivka, in the valley of Rzhavchyk River. The Nova Vodolaga landfill (0.0683 km^2) *(Figure 2f)* is found within 500 meters of the Nova Vodolaga town periphery (Dementieieva 2022).

The area of landfills can be divided into different functional zones, which are unevenly occupied by birds (Marasinghe *et al.* 2018). The epicenter of the landfill is the dumping point of "fresh waste", which changes according to the logistics and landfill filling plan. Operating landfill is the territory that includes the epicenter and receives waste at the current stage of operation. Reclaimed landfills are the territories that underwent reclamation and no longer accept waste. Ruderal zones are the areas along the perimeter of the landfill, which have a linear elongated shape, strongly transformed soils and ruderal vegetation. Natural biotope zones are usually small areas not subjected to human intervention. These areas are used differently by birds, and, accordingly, their density and types of diversity have differences.

Quantitative indicators of the presented species also differ. The main dominants and absolutely typical for landfills are crows (Corvidae) and gulls (Laridae), as well as the following species: Common Starling *(Sturnus vulgaris)*, Feral Pigeon *(Columba livia)*, Eurasian Tree Sparrow *(Passer montanus)* and House Sparrow *(Passer domesticus)*. Among birds of other species, significant fluctuations in numbers are not observed.

Landfills serve as nesting, wintering, and roosting areas, and also serve as stopover sites of migration corridors (Arizaga *et al.* 2018). So, we categorize the bird species as follows:

Sedentary species stay in the studied area throughout the year.

Nestling species nest in the studied territory and leave the area after the end of the reproductive period.

Wintering species occur only during winters.

Wandering species do not nest in the study area, but regularly appear in the summer.

Migratory species do not nest nearby, but use the area as stopover sites during seasonal migration.

Vagrants occasionally appear in the study area only during the migration period (Potish 2009).

We determined the relative abundance by Belyk (2000): very rare species (1–5 sightings during all years of research); rare species (6–10 sightings); low-number species (regular, but not annual sightings); ordinary (regular annual observations); numerous (1–10 sightings per day); abundant (more than 10 sightings per day).

To quantify the study intensity of landfill avifauna in the Kharkiv region, we used the Chao1 index, which shows the prospect of new discoveries of species diversity in the perspective of further research $chao1 = S\,obs + \frac{f_1^2}{2f_2^2}$, and Turings index $S_T = \frac{S_{obs}^2}{S_{obs} - f_1}$. Both indexes take into account the variables of singletons (one-time encounters of species representatives) and doubletons (two-time encounters).

Species diversity and abundance were characterized by the Menhinick index $D_{Mn} = \frac{S}{\sqrt{N}}$, where S is the number of species in the study area, N is the number of encounters. The higher is the ratio of the average share of one species per one sample, the greater is the species diversity of the studied territory. We also applied the Shannon index $\mathrm{H} = -\Sigma p_i \log 2\, p_i$, where p_i is the relative abundance of species (the dependence of representatives of a species on the total number of individuals of all species). The latter, according to the same principle, quantifies the diversity in accordance with the principle of maximum diversity, when all individuals of a group belong to different species, or zero, when all individuals belong to the same species.

The evenness of the grouping structure has been analyzed by using the Pielow index $E_H = \frac{H}{H_{max}}$, where H_{max} – the maximum value of Shannon index.

To determine the significance of the species, we use the Berger-Parker index $D_{BP} = \frac{n_{max}}{N}$, where n_{max} is the number of individuals of the most abundant species.

For convenience, the values are presented as 1/d. The index values are always in the range from zero to one, where zero indicates no dominance and one means absolute dominance.

We determined the difference of the territories by dominant species value indices; diversity, abundance and evenness of bird groups, which were displayed in the dendrogram. The graph was made by STATISTICA program thanks to the cluster analysis of hierarchical classification according to Berger-Parker, Menhinik, Shannon and Pielow index calculations.

Jacquard and Sørensen indices were used to compare the studied territories with each other, as well as to analytically determine the difference between the object of study in the Kharkiv region and the data of the Crimean peninsula. $C_j = \frac{c}{a+b-c}$, $C_s = \frac{2C}{a+b}$,where “a” is the number of species in the first biota, “b” the number of species in the second biota, “c” the number of species common to both biota.

Results

As of 2022, the known species richness of birds at landfills of the Kharkiv region is 73 species, 56 genera, 27 families, 11 orders. The species richness of the landfills consists of 61 and 56 species at the Dergachy and Rohan landfills of Kharkiv city, 52 and 51 species at the Lozova and Kupyansk landfills, and 50, 43, 39 at the Zmiiv, Merefa, and Nova Vodolaga landfills, respectively. It is worth noting that there is a bias in the study due to the uneven observation at different landfills of Kharkiv region. Technically, we built the study with an emphasis on Kharkiv landfills as the most representative test objects.

Our records covered 73% of the total (unknown) species richness, as assessed by the Chao1 species richness estimate. Results close to 75% are considered sufficient studies of the object and indicate a reliability of the compiled list. In addition, we calculated the Turing index, the value of which reached 74%, which confirms the reliability of our results.

A significant share of the species registered at the landfills are nesting – 33% and sedentary – 20%; 17% and 14% are migratory and wandering, respectively; 10% – occasional are vagrants on the area of landfills, and 6% – species that exclusively winter on the territory of landfills *(Figure 2a)*.

By relative abundance: the numerous (up to 10 occurrences) and ordinary species account for 37 and 25%, respectively, of the entire bird fauna of landfills, while the abundant (>10 occurrences) have a share of 11%. The rare, the very rare, and the low-number species constitute 27% of the species richness *(Figure 2b)*.

The species diversity of landfills is unevenly distributed. The density of birds in the zones of the landfills differed significantly *(Figure 2c)*. The greatest diversity of species is noticeable along the perimeter of landfills in ruderal landscapes and natural areas – 30 and 24%, respectively. At the operating landfill, including the epicenter, 30% of species are recorded. The least diverse are usually the territories of reclaimed areas of landfills. Here the following species are important for nesting in small numbers: Gray Partridge *(Perdix perdix)*, Greenfinch *(Carduelis chloris)*, Common Linnet *(Acanthis cannabina)*, Sedge Warbler *(Acrocephalus schoenobaenus)*, Marsh Warbler *(A. palustris)*, Common Whitethroat *(Sylvia communis)*, Barred Wabler *(Curruca nisoria)*, Western Yellow Wagtail *(Motacilla flava)*, Bluethroat *(Luscinia svecica)*, and also predators: Rough-legged Buzzard *(Buteo lagopus)*, Northern Goshawk *(Accipiter gentilis)*, and Eurasian Sparrowhawk *(A. nisus)*.

Among the birds belonging to landfills, 22 species are protected by several conventions *(Figure 2d)*. The most widespread are species protected by the Bern Convention, many of which are also protected by other regulatory documents. Species listed in the Red Book of

Figure 3. A flock of Black Kite *(Milvus migrans)*. Rogan landfill, Kharkiv, Ukraine 17.06.2020
3. ábra Barna kánya csapat *(Milvus migrans)*. Rogan hulladéklerakó, Harkov, Ukrajna 2020.06.17.

Ukraine and the IUCN are registered at the landfills: Hen Harrier *(Circus cyaneus)*, Stock Dove *(Columba oenas)* and Black Kite *(Milvus migrans)*. The latter formed significant groups in the research area *(Figure 3)*.

Seven species are categorized as dominants, forming groups of 200 or more individuals – Rook *(Corvus frugilegus)*, Jackdaw *(Corvus monedula)*, Common Starling, Caspian Gull *(Larus cachinnans)*, Black-headed Gull *(Chroicocephalus ridibundus),* Feral Pigeon, Eurasian Tree Sparrow. We calculated the Berger-Parker index divided by one for these species, which shows the significance of each species. The index was 3.86 for the Rook, 5.15 – for the Jackdaw, 5.72 – for the Common Starling, 7.72 – for the Caspian Gull, 17.16 – for the Black-headed Gull, 38.61 – for the Feral Pigeon, and 30.89 – for the Eurasian Tree

Figure 4. White Stork *(Ciconia ciconia)*, Rogan landfill, Kharkiv, Ukraine 18.07.2021
4. ábra Fehér gólya (Ciconia ciconia), Rogan hulladéklerakó, Harkov, Ukrajna 2021.07.18.

Sparrow. Subdominants birds that form groups of 20 to 150 individuals included – Raven *(Corvus corax)*, Magpie *(Pica pica)*, Hooded Crow *(Corvus cornix)*, Great Tit *(Parus major)*, Goldfinch *(Carduelis carduelis)*, Eurasian Collared Dove *(Streptopelia decaocto)* and White Stork *(Ciconia ciconia)*. The latter species is currently of much interest among researchers, as landfills in Western Europe have greatly increased their population size. We have recorded groups of up to 40 individuals on the Kharkiv landfills (Dementieieva 2021b) *(Figure 4)*.

An increase in the significance index of the most numerous species means a decrease in diversity and an increase in the degree of dominance of one species. In this case, the importance of the Rook and Jackdaw as dominants, respectively, is clearly visible.

The Common Redstart *(Phoenicurus phoenicurus)*, House Sparrow, Crested Lark *(Galerida cristata)*, White Wagtail *(Motacilla alba)*, Western Yellow Wagtail *(Motacilla flava)*, etc. occur less frequently than the dominant or subdominant species. They mainly visit sandy areas, artificial water bodies, and adjacent agricultural areas.

Calculations of indices of species abundance by Menhinick and Shannon for the landfill areas of Kharkiv region showed results of 0.83 and 2.26, respectively. Thus, the Menhinick abundance index is higher, the greater the species abundance of the studied territory. An increase in the number of individuals with an unchanged number of species leads to a decrease in the value of Shannon's diversity index, which usually varies from 1.5 to 3.5, so our results show a rather high diversity of avifauna of landfills in the region. Its evenness according to the Pielow index equals 0.53. This shows the structure of the bird assemblage at the region's landfills to be uneven, because the quantitative characteristics of the species diversity should strive to reach the maximum possible value.

According to the calculations of the Berger-Parker, Menhinik, Shannon and Pielow indices, we determined the difference of the territories by the indicators of the value of the dominant species, diversity, abundance and evenness of bird groups *(Figure 5)*.

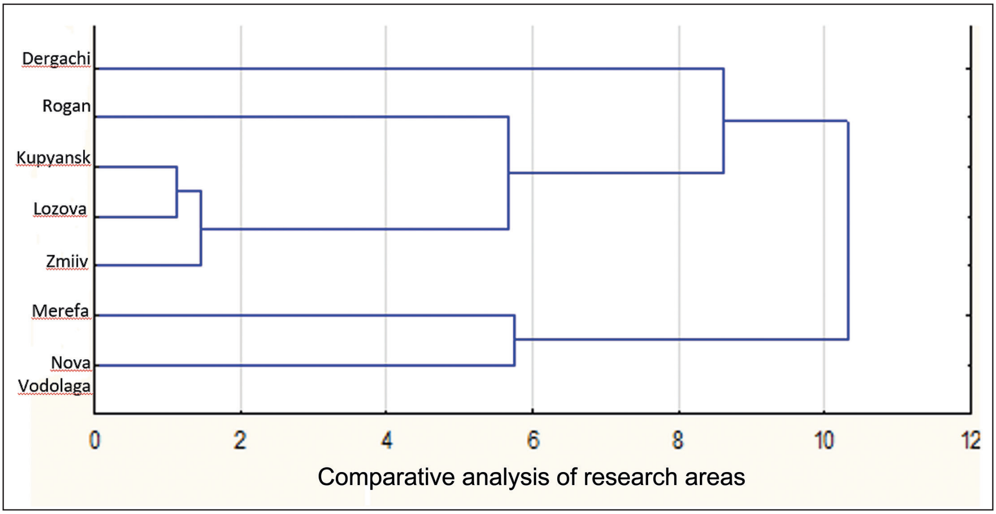


Figure 5. Cluster analysis of landfill differences by Jaccard and Sørenson similarity indices
5. ábra A hulladéklerakók közötti különbségek elemzése Jaccard és Sørenson hasonlósági mutatók felhasználásával

Based on the obtained results, we concluded that the small landfills of Kupyansk and Lozova are most similar to each other. This can be explained by similar biotope conditions, and proximity to sewage treatment plants. The conditions make it possible for avifauna to be more evenly distributed, which means to avoid strong dominance of individual species. Similar conditions for the formation of birds' community, very close to natural condition, are in Zmiiv, because there is a large forest massif nearby. The forest creates conditions for various species of birds and eliminates the problem of the concentration number of animals near an artificial fodder resource. The Rohan landfill is the last in the list of territories similar by species diversity and abundance, because despite the aggregation of birds it showed very low indices of dominant species value. These indicators are lower than in Dergachi, which, in turn, affects the evenness index of Pielow grouping. Special attention should be paid to Merefa and Novaya Vodolaga landfills, because their indicators differ significantly both among themselves and with other territories. The Merefa landfill occupies a relatively small area and is limited by the species composition. Due to this, the role of dendrogram variables in relation to uniform distribution, as well as the value of dominants, is growing. Moreover, Nova Vodolaga is defined as a fairly uniform structure, but here as well as the Merefa landfill, the specifics of places are very similar. Both places are limited territories that close to and rises above settlements.

Since indices of species diversity strongly depend on the number of representatives, they were also determined separately by Jaccard and Sørenson similarity indices to compare all the species composition landfills in the Kharkiv region.

The Dergachy and Rohan landfills, which serve the regional center of the city of Kharkiv, are the most similar. The similarity is (0.79) of common species for the two sites, which is explained by the proximity of the territories and the large area. The lowest similarity index was shown by the sections of the Nova Vodolaga and Zmiiv landfills (0.5). Although the distance is the same as between the Dergachy and Rohan ones, the lack of similarity must be explained by the fact that the Zmiiv landfill has a much shorter period of formation. Besides, it possesses the largest protective zone with woody vegetation, and lies in the proximity of a large forest of the Gomilshan Forests National Park, which also attracts a variety of birds. The Zmiyiv landfill generally does not have high similarity indices with all landfills. This indicates the lowest degree of transformation of this biotope. The solid waste landfills of the cities of Lozova and Kupyansk have a significant similarity (0.69), despite their distance. This can be explained by the proximity of both landfills to biological treatment facilities for standing water and filtration fields. Such biotopes form seminatural habitat complexes, specific and similar in species composition.

Discussion

The largest number of species we recorded within the Dergachy and Rohan landfills – 61 and 56 species, respectively. This is primarily due to the size of these landfills, which serve the metropolis, the largest city of the Kharkiv region, and have the most diverse morphological composition of waste.

Analyzing the obtained data, it is possible to conclude the significant role of landfills for birds of different ecological groups, which differ in the status of their habitat in the territory and its use. Thus, more than half (53%) of the species use the area as a nesting or permanent residence. This points out at the exceptional role of landfill areas for birds.

The territory is very densely populated, in addition, dominant species play a very important role. They are numerous – up to 10 or more encounters per excursion, which makes a total of 48% of all birds. Seven species of birds are dominant in number, which in different seasons of the year form large gatherings, up to 2,000 individuals of the Rook, up to 1,500 thousand starlings and jackdaws, up to 1,000 martins and up to 3 hundreds pigeons and sparrows. The Rook is defined as an absolute dominant, as is the Corvidae in particular and in general, which is also confirmed by other ornithological studies of landfills in continental zones.

The avifauna of landfills has specific formation factors, which are primarily related to factors of anthropogenic influence – pollution and changes in environmental conditions, a significant increase in the number and availability of food resources and their proximity to populated areas, etc. (Dementieieva 2022). This all leads to the concentration of bird species in these areas. Of course, the species composition is influenced by natural factors such as proximity to water bodies and climatic conditions, which shape the conditions for the regional biota. However, the avifauna of landfills is always less rich than the species composition of the surrounding habitats and is characterized by a low degree of evenness. The dominance of individual species in the avifauna of landfills is emphasized in all studies of landfill fauna that were considered, as stated in Materials.

The number of birds at a landfill depends on the weather conditions and the season of the year. Thus, birds of the Corvidae are en masse at the landfill in the winter, while in the summer, birds of the Gull and Stork families, in particular, the White Stork, reach large numbers.

A related study of the avifauna of landfills in Ukraine was conducted in the Crimean peninsula at the end of the last century (Kostin 1996). Sixty-one species of birds were registered at four investigated sites. Of these, 30 species share the same as those observed at the Kharkiv landfills, which gives a value of 0.27 when calculating the Jaccard index. This indicates a significant difference in the species composition of birds of landfills in different regions of Ukraine, which is easily explained by differences in the physical-geographical and anthropogenic factors. However, the dominant species and the structure of the zonal placement of birds at landfills determined in the work of S. Yu. Kostin show the features in the formation of landfill avifauna that are also characteristic of many other landfills on the continent and around the world. The author points out at birds of the Gull family, e.g. the Caspian Gull*)*, as the dominant birds. Similar data are noted in the coastal zones of other countries (Meissner & Betleja 2007, Rumbold *et al.* 2009, Abigail 2013, Caron-Beaudoin *et al.* 2013, Chen 2013, Bárbara *et al.* 2017, O'Hanlon *et al.* 2017, Martín-Maldonado *et al.* 2020, Rao *et al.* 2021, Soualah *et al.* 2021, etc.). Since the Kharkiv region is located at a significant distance from the seacoast, gulls are inferior to other types of birds in dominant positions here. Thus, birds of Corvidae, which are subdominant for landfills of the Crimean Peninsula, are, on the contrary, absolute dominants at landfills in the Kharkiv region, as well as non-coastal zones in other countries (Vuorisaloa *et al.* 2003, Marasinghe *et al.* 2018, Noreen & Sultan 2021, Soualah *et al.* 2021, etc.). Common Starlings and pigeons are among the dominant species of the continental zones, including the Kharkiv region (Soualah *et al.* 2021). Across several European and American landfills near the seashores, storks, herons and egrets are often noted (Burger *et al.* 1993, Rumbold *et al.* 2009, Abigail *et al.* 2013, Jagiello *et al.* 2018, Marasinghe *et al.* 2018, Bialas *et al.* 2020, Rabaça *et al.* 2020, Bialas *et al.* 2021, Rao *et al.* 2021). These are also recorded in Kharkiv region. The White Stork was concentrated in groups of up to 40 individuals for the past few years, and the Gray Heron are registered exclusively as transient during migration.

The zonal distribution of birds relative to the territory of landfills is also similar between Kharkiv region and Crimean Peninsula. Thus, a group of dominant birds is concentrated in the epicenter of the landfill, or the active area of waste discharge, as defined by Kostin (Kostin 2020). It is interesting, that birds of Corvidae, e.g. the Rook, the Jackdaw, the Raven, and the Hooded Crow in both regions show the same feeding behavior. They search for food in the epicenter of the landfill and fly around its perimeter to eat and rest. The Common Starling and pigeons, which are found in large groups in the epicenter of landfill, have the same behavior and preference in both regions' landfills. Small sparrow-like and other small species, including nesting species, e.g. the Magpie, the Gray Partridge, etc. are mostly registered outside the perimeter of the landfill, regardless of where the foraging process takes place: either in ruderal zones, stands of trees or waste masses.

Large number of Ravens and Gulls in both regions use landfill sites for wintering, which emphasizes the role of landfills during unfavorable periods.

Conclusions

Our investigations of landfill avifauna of in the Kharkiv region allow us to state that, despite the significant technogenic influence, these territories play a special role in supporting the bird population, and are a place of concentration of not only widespread, but also rare species. In general, the presence of bird species was found on the territory of the landfills, where there are rare and endangered species listed in the Red Book of Ukraine *(Circus cyaneus, Columba oenas, Milvus migrans)*. Solid household waste landfills, which are large in acreage, are characterized by a high degree of dominance of certain species, which negatively affect interspecies relations among representatives of the avifauna. Dominance as opposed to species diversity makes the ecosystem more vulnerable and incapable of self-recovery.

Waste landfills are an urgent environmental problem that requires changes in environmental management, work with the population and industry regarding waste formftion, as well as a careful and delicate solution to the problem of waste isolation, taking into account the needs of the animal world formed at landfills.

References

Abigail, K., Rosina, K., Daniel, A. K. & Holbech, L. H. 2013. Foraging activities, success and efficiency of Cattle Egrets *(Bubulcus ibis)* in three habitat types in the Greater Accra Region of Ghana. – Journal of Biological and Food Science Research 2(4): 45–50.

Anand, U., Reddy, B., Singh, V. K., Singh, A. K., Kesari, K. K., Tripathi, P., Kumar, P., Tripathi, V. & Simal-Gandara, J. 2021. Potential environmental and human health risks caused by antibiotic-resistant bacteria (ARB), antibiotic resistance genes (ARGs) and emerging contaminants (ECs) from municipal solid waste (MSW) landfill. – Antibiotics 10(4): 1–27. DOI: 10.3390/antibiotics10040374

Arizaga, J., Resano-Mayor, J., Villanúa, D., Alonso, D., Barbarin, J. M., Herrero, A., Lekuona, J. M. & Rodríguez, R. 2018. Importance of artificial stopover sites through avian migration flyways: a landfill-based assessment with the White Stork *Ciconia ciconia*. – Ibis 160(3): 542–553. DOI: 10.1111/ibi.12566

Bárbara, A., Torrontegi, O., Camacho, M-C., Barral, M., Hernández, J-M. & Höfle, U. 2017. Avian influenza virus surveillance in South-Central Spain using fecal samples of aquatic birds foraging at landfills. – Frontiers in Veterinary Science, Section Veterinary Epidemiology and Economics 4: 1–8. DOI: 10.3389/fvets.2017.00178

Belant, J. L. 1997. Gulls in urban environments: landscape-level management to reduce conflict. – Landscape and Urban Planning 38(3–4): 245–258. DOI: 10.1016/S0169-2046(97)00037-6

Belant, J. L., Seamans, Th. W., Gabrey, S. W. & Ickes, Sh. K. 1993. Importance of landfills to nesting Herring Gulls. – The Condor 95(4): 817–830. DOI: 10.2307/1369420

Belyk, V. P. 2000. Ptytsy stepnogo Prydonia. Formyrovanye fauny, antropogennaia transformatsyia i voprosy ohrany [Birds of the steppe Don region. Fauna Formation, Anthropogenic Transformation and Conservation Issues]. – Rostov-na-Donu. 276 s. (in Russian)

Bialas, J. T., Dylewski, Ł. & Tobolka, M. 2020. Determination of nest occupation and breeding effect of the White Stork by human-mediated landscape in Western Poland. – Environmental Science and Pollution Research 27: 4148–4158. DOI: 10.1007/s11356-019-06639-0

Bialas, J. T., Dylewski, Ł., Dylik, A., Janiszewski, T., Kaługa, I., Królak, T., Kruszyk, R., Pawlukojć, K., Pestka, Z., Polakowski, M., Zbyryt, A. & Tobolka, M. 2021. Impact of land cover and landfills on the breeding effect and nest occupancy of the White Stork in Poland. – Scientific Reports 11(7279): 1–14. DOI: 10.1038/s41598-021-86529-z

Blanco, G. & Bautista, L. M. 2020. Avian scavengers as bioindicators of antibiotic resistance due to livestock farming intensification. – International Journal of Environmental Research and Public Health 17(3620): 1–13. DOI: 10.3390/ijerph17103620

Burger, J. & Gochfeld, M. 1983. Behavior of nine avian species at a Florida Garbage Dump. – Colonial Waterbirds 6: 54–63. DOI: 10.2307/1520967

Carlin, J. 2019. Investigation of microplastic accumulation in the gastrointestinal tract in birds of prey. – Honors Undergraduate Theses 501: 1–29.

Caron-Beaudoin, É., Gentes, M-L., Patenaude-Monette, M., Hélie, J-F., Giroux, J-F. & Verreault, J. 2013. Combined usage of stable isotopes and GPS-based telemetry to understand the feeding ecology of an omnivorous bird, the Ring-billed Gull *(Larus delawarensis)*. – Canadian Journal of Zoology 91(10): 689–697. DOI: 10.1139/cjz-2013-0008

Chen, D., Martin, P., Burgess, N. M., Champoux, L., Elliott, J. E, Forsyth, D. J., Idrissi, A. & Letcher, R. J. 2013. European Starlings *(Sturnus vulgaris)* suggest that landfills are an important source of bioaccumulative flame retardants to Canadian terrestrial ecosystems. – Environmental Science & Technology 47(21): 1–4. DOI: 10.1021/es403383e

de la Casa-Resino, I., Hernández-Moreno, D., Castellano, A., Pérez-López, M. & Soler, F. 2014. Breeding near a landfill may influence blood metals (Cd, Pb, Hg, Fe, Zn) and metalloids (Se, As) in White Stork *(Ciconia ciconia)* nestlings. – Ecotoxicology 23: 1377–1386. DOI: 10.1007/s10646-014-1280-0

Dementieieva, Y. Y. 2021a Ornitofauna polihoniv tverdykh pobutovykh vidkhodiv mista [Ornithofauna of solid waste landfills of the Kharkov city]. – Cherkasy University Bulletin Biological Sciences Series 1: 26–36. DOI: 10.31651/2076-5835-2018-1-2021-1-26-36 (in Ukrainian)

Dementieieva, Y. Y. 2021b Leleka bilyi *(Ciconia ciconia)* na polihonakh skladuvannia tverdykh pobutovykh vidkhodiv m. Kharkova Mizhnarodna naukovo-praktychna internet-konferentsiia [White Stork *(Ciconia ciconia)* at waste landfills in Kharkiv]. – International Scientific and Practical Internet Conference «Ekolohichno stalyi rozvytok urbosystem: vyklyky i rishennia» KhNUMH im. O. M. Beketova (in Ukrainian)

Dementieieva, Y. Y. 2022. Zymova ornitofauna polihoniv tverdykh pobutovykh vidkhodiv Kharkivskoi oblasti [Winter avifauna of solid waste landfills of Kharkiv region]. – Ukraina Bioriznomanittia, Ekolohiia ta Eksperymentalna Biolohiia 24(1): 12–24. DOI: 10.34142/2708-5848.2021.24.1.02 (in Ukrainian)

Dementieieva, Y. Y., Andrusenko, L. Y., Mukhina, O. Y. & Chepurna, N. P. 2021. Vmist vazhkykh metaliv v orhanizmakh herpetobiontnykh chlenystonohykh tvaryn na terytorii polihoniv tverdykh pobutovykh vidkhodiv mista Kharkova [Heavy metals content in herpetobiontic arthropoda on the territory of landfills of the Kharkiv city]. – Visnyk of V. N. Karazin Kharkiv National University series «Ecology» 24: 117–125. DOI: 10.26565/1992-4259-2021-24-10 (in Ukrainian)

Jagiello, Z. A., Dylewski, Ł., Winiarska, D., Zolnierowicz, K. M. & Tobolka, M. 2018. Factors determining the occurrence of anthropogenic materials in nests of the White Stork *Ciconia ciconia*. – Environmental Science and Pollution Research 25: 14726–14733. DOI: 10.1007/s11356-018-1626-x

Jarma, D., Sánchez, M. I., Green, A. J., Peralta-Sánchez, J. M., Hortasa, F., Sánchez-Melsió, A. & Borregode, C. M. 2021. Faecal microbiota and antibiotic resistance genes in migratory waterbirds with contrasting habitat use. – Science of the Total Environment 783: 1–11. DOI: 10.1016/j.scitotenv.2021.146872.

Kostyn, S. I. 2020. Mesto s znachenye ruderalnykh kompleksov v urbolandshafte [Place with the importance of ruderal complexes in the urban landscape]. – Russkyi Ornytolohycheskyi Zhurnal 29: 721–724. (in Russian)

Kostyn, S. Y. 1996. Fauna, raspredelenye i chyslennost ptyts na polyhonakh tverdykh bytovykh otkhodov v Krymu [Fauna, distribution and abundance of birds in solid waste landfills in the Crimea]. – Pratsi Ukrainskoho Ornitolohichnoho Tovarystva, T. 1. S. 94–112. (in Russian)

Marasinghe, S. S., Perera, P. K. P. & Dayawansa, P. N. 2018. Putrescible waste landfills as bird habitats in urban cities: a case from an urban landfill in the Colombo district of Sri Lanka. – Journal of Tropical Forestry and Environment 8(2): 29–41. DOI: 10.31357/jtfe.v8i2.3761

Martín-Maldonado, B., Vega, S., Mencía-Gutiérrez, A., Lorenzo-Rebenaque, L., de Frutos, C., González, F., Revuelta, L. & Marin, C. 2020. Urban birds: An important source of antimicrobial resistant Salmonella strains in Central Spain. – Comparative Immunology, Microbiology and Infectious Diseases 72: 101519. DOI: 10.1016/j.cimid.2020.101519

Mcgrady, M. J. & Alfazari, W. 2013. Counts of Egyptian Vultures *Neophron percnopterus* and other avian scavengers at Muscat's municipal landfill, Oman, November 2013.–March, 2016. – Sandgrouse 3: 99–105.

Meissner, W. & Betleja, J. 2007. Skład gatunkowy, liczebność i struktura wiekowa mew Laridae zimujących na składowiskach odpadów komunalnych w Polsce [Species composition, numbers and age structure of gulls Laridae wintering at rubbish dumps in Poland]. – Notatki Ornitologiczne 48: 11–27. (in Polish with English Summary)

Michalicha, M. & Pitucha, G. 2019. Wpływ składowisk odpadów na ptaki [Impact of landfills on birds]. – Polish Journal for Sustainable Development 23(2): 63–72. DOI: 10.15584/pjsd.2019.23.2.7 (in Polish with English Summary)

Noreen, Z. & Sultan, Kh. 2021. Population explosion and behavioural changes of opportunist wild avifauna at a landfill at Gujranwala in Northeastern Punjab: A baseline deviation study. – Pakistan Journal of Zoology 53(6): 2001–2521. DOI: 10.17582/journal.pjz/20200211050231

O'Hanlon, N. J., McGill, A. R. & Nager, R. G. 2017. Increased use of intertidal resources benefits breeding success in a generalist gull species. – Marine Ecology Progress Series 574: 193–210. DOI: 10.3354/meps12189

Parejo, S. H., Martínez-Carrasco, C., Diaz, J. I., Chitimia, L., Ortiz, Ju., Mayo, E. & de Ybáñez, R. R. 2015. Parasitic fauna of a Yellow-legged Gull colony in the island of Escombreras (South-eastern Mediterranean) in close proximity to a landfill site: potential effects on cohabiting species. – Acta Parasitologica 60(2): 290–297. DOI: 10.1515/ap-2015-0041

Pellissier, V., Cohen, M., Boulay, A. & Clergeau, Ph. 2012. Birds are also sensitive to landscape composition and configuration within the city centre. – Landscape and Urban Planning 104(2): 181–188. DOI: 10.1016/j.landurbplan.2011.10.011

Potish, L. 2009. Ptakhy Zakarpatskoi oblasti (anotovanyi spysok) [Birds of the Transcarpathian region of Ukraine (annotated list)]. – Lviv https://dspace.uzhnu.edu.ua/jspui/handle/lib/3177 (in Ukrainian)

Rabaça, J. E., Ventura, T., Faria, N. & Roque, I. 2020. Foraging in landfills: Feeding behavior of the White Stork *(Ciconia ciconia)* and kleptoparasitism by Black Kites *(Milvus migrans)*. – The Wilson Journal of Ornithology 132(3): 513–521. DOI: 10.1676/19-10

Rao, S., Nicastro, K. R., Christopher, C. M., McQuaid, D. B. & Zardi, G. I. 2021. A 6-year survey of plastic ingestion by aquatic birds in southern Portugal. – Marine and Freshwater Research 73(4): 478–490. DOI: 10.1071/MF21221

Ruiz-Ripa, L., Gómez, P., Alonso, C. A., Camacho, M. C., Ramiro, Y., de la Puente, J., Fernández-Fernández, R., Quevedo, M. Á., Blanco, J. M., Báguena, G., Zarazaga, M., Höfle, U. & Torres, C. 2020. Frequency and characterization of antimicrobial resistance and virulence genes of coagulase-negative Staphylococci from wild birds in Spain. Detection of tst-Carrying S. Sciuri Isolates. – Microorganisms 8(9): 1–12. DOI: 10.3390/microorganisms8091317

Rumbold, D. G., Morrison, M. & Bruner, M. C. 2009. Assessing the ecological risk of a municipal solid waste landfill to surrounding wildlife: A case study in Florida. – Environmental Bioindicators (4): 246–279. DOI: 10.1080/15555270903025456

Saalfeld, S. T., Hill, B. L. & Lanctot, R. B. 2013. Shorebird responses to construction and operation of a landfill on the Arctic coastal plain. – The Condor 115(4): 816–829. DOI: 10.1525/cond.2013.120169

Soualah, A. H., Difi, N., Benhachiche, A. & Ponsero, A. 2021. Seasonal fluctuation of birds in open landfill, Souk Ahras (Algeria). – Genetics & Biodiversity Journal 5(1): 12–19. DOI: 10.46325/gabj.v5i1.159

Tongue, A. 2020. Gulls (Laridae) as bioindicators of flame retardant emissions from landfill: a species-assemblage investigation. – University of Birmingham

Turrin, C., Watts, B. D. & Mojica, E. K. 2015. Landfill use by Bald Eagles in the Chesapeake Bay Region. – Journal of Raptor Research 49(3): 239–249. DOI: 10.3356/JRR-14-50.1

Vuorisaloa, T., Anderssonb, H., Huggc, T., Lahtinena, R., Laaksonend, H. & Lehikoinene, E. 2003. Urban development from an avian perspective: causes of Hooded Crow *(Corvus corone cornix)* urbanisation in two Finnish cities. – Landscape and Urban Planning 62(2): 69–87. DOI: 10.1016/S0169-2046(02)00124-X

Zduniak, P., Bocheński, M. & Maciorowski, G. 2021. How littered are birds' of prey nests? Study of two sympatric species. – Science of the Total Environment 790: 148079. DOI: 10.1016/j.scitotenv.2021.148079

Ornis Hungarica 2023. 31(1): 62–71.
DOI: 10.2478/orhu-2023-0004

Natural remnants are refuges for rare birds in an urban area: a study from Pune city, India

Kiran Choudaj[1,2*] & Chaitali Shaha[1,3]

Received: February 06, 2023 – April 20, 2023 – Revised: April 27, 2023

Choudaj, K. & Shaha, C. 2023. Natural remnants are refuges for rare birds in an urban area: a study from Pune city, India. – Ornis Hungarica 31(1): 62–71. DOI: 10.2478/orhu-2023-0004

Abstract The green spaces in many urban areas are under severe threats; the area under green cover is declining, habitat quality is deteriorating due to fast urbanisation and the booming real estate market. Therefore, we investigated the avian richness of a natural remnant area and compared it with species richness data previously published in the literature about gardens, urban parks, and academic campuses in Pune, India. In two years of our survey, we recorded 65 species at the natural remnant site, 15 of which are rare considered in urban areas. Among recorded species, 17 are habitat specialists and 14 have declining population. Natural remnant patches are generally inaccessible to the general public; they have undergrowth of vegetation and aerial leaf litter, which may be the reason for the higher species richness and the occurrence of rare species. Our findings indicate that the natural remnant site in Pune has a unique and relatively rich assemblage of bird species, thus provide further support for the notion that natural remnant sites are valuable for urban biodiversity conservation. Therefore, we suggest that small, isolated patches of natural vegetation should receive more attention in conservation planning.

Keywords: avifauna, ecological value, native vegetation, unique biodiversity, urban ecology and sustainability

Összefoglalás A zöldfelületek sok városi területen komoly veszélynek vannak kitéve; a területük csökken, az élőhelyek minősége romlik a gyors urbanizáció és a fellendülő ingatlanpiac miatt. Jelen vizsgálatban összehasonlítottuk a megmaradt természetes területek fajgazdagságát a korábban Pune-i kertekből, városi parkokból és egyetemi kampuszokból megjelent szakirodalmi adatokkal. Felmérésünk két éve alatt 65 fajt rögzítettünk ezeken a maradványterületeken, amelyek közül 15 ritka a városi környezetben. A nyilvántartott fajok közül 17 élőhelyspecialista, 14 csökkenő állományú. A természetes visszamaradt foltok a nagyközönség számára hozzáférhetetlenek; aljnövényzetük dús, és jelentős a lombozatban rekedt lehulló falevelek aránya is. Ez lehet az oka a magasabb fajgazdagságnak és a ritka fajok előfordulásának. Eredményeink azt mutatják, hogy a természetes élőhelymaradványok egyedülálló madárfajtársulásokkal rendelkeznek; ezek a maradványok értékesek a városi biodiverzitás megőrzése szempontjából. A természetvédelmi tervezés során előnyben kell részesíteni a kis, elszigetelt, természetes növényzetfoltokat.

Kulcsszavak: madárvilág, ökológiai érték, őshonos növényzet, egyedülálló biodiverzitás, városökológia és fenntarthatóság

[1] *Department of Zoology, Savitribai Phule Pune University, Ganeshkhind, Pune, India 411007*
[2] *Department of Biodiversity, Abasaheb Garware College, Karve Road, Pune, India 411004*
[3] *Department of Zoology, Modern College of Arts, Commerce and Science, Ganeshkhind, Pune, India, 411007*
** corresponding author, e-mail: kiranchoudaj@gmail.com*

Introduction

Cities are expanding rapidly around the world in both size and density, significantly impacting urban ecosystems. More than half of the world's population lives in urban areas, and it is expected to reach six billion by 2041 (United Nations 2018). Urban growth leads to deforestation, which diminishes ecosystem services that are beneficial to people and biodiversity. Urbanisation affects various spheres of society, the environment, and biodiversity (Parris 2016). Urbanisation generally decreases the variety of plant species, homogenises the habitat, encourages invasive non-native species, modifies phenological occurrences, and due to pollution, may hinder plant development (Raus *et al.* 2022). Urban green spaces are one of the most important elements of any urban ecosystem because of their dynamism and their essential contribution to the well-being of mankind. In urban habitats, at first, the original vegetation is cleared due to the need for land for buildings, and later, artificial landscapes are created in the newly developed areas. The composition and structure of artificial landscapes are also changing in urban habitats; gardens that used to have local plants are replaced by turf grass and exotic plants in landscape design (Nagendra & Gopal 2010, Nagendra 2016). These artificial landscapes are created mainly for recreational activities, and less attention is paid to their ecological role. The turf grass and exotic ornamental plants that dominate urban green spaces make it difficult for native plants to grow and offer little habitat for wildlife (Choudaj & Wankhade 2022).

The urban habitat is primarily composed of housing developments and retains very low species diversity (Sewell & Catterall 1998). Urbanisation has an impact on bird populations, and species richness typically diminishes in urban settings, leading to assemblages of generalist and urban-adapted species (Chace & Walsh 2006). Remnant natural vegetation is vital for the sustainability of urban wildlife since it provides resources such as food and shelter for many species; bird diversity is positively associated with retaining native vegetation within the urban matrix (Evans *et al*. 2009). It was reported that green areas with native vegetation have a greater richness of bird species than recently developed artificial landscapes with exotic vegetation (Sewell & Catterall 1998, Chace & Walsh 2006).

Currently, urbanisation is rapid in India, which will have the world's largest urban population by 2050 (United Nations 2019). Despite the importance of natural vegetation, human settlements have encroached on additional land that is needed to keep up with the unsustainable growth of the human population. Pune is one of the fastest-growing metropolitan areas in Asia, and Pune Municipal Corporation has become the largest in the Maharashtra state of India. The influx of people to the Pune urban area has created a huge demand for land for infrastructure and housing projects that are transforming native vegetation and agricultural land into built-up areas (Butsch *et al.* 2017). The use of exotic plants for urban beautification is increased in Pune; exotic plantations over hills are present in the city (Punalekar *et al.* 2010); a higher percentage of exotic plants is common in newly created gardens and parks (Choudaj & Wankhade 2022).

Urban sprawl intruded on all natural habitats in the Pune urban area, and as a result, bird diversity has decreased across all the habitats (Ingalhalikar *et al*. 2001). Nerlekar *et al.* (2016) and Choudaj and Wankhade (2021a) studied the avifauna of premier academic institutions in Pune city, noted decline in richness of birds due to loss of suitable habitat. Exotic plantations over the native savannas of Pune city affected grassland birds (Choudaj & Wankhade 2021b). Small green spaces with native plants support more birds, but increasing percentage of exotic plants negatively affect them, especially the specialist ones (Choudaj & Wankhade 2022). All the habitats in the Pune urban area have been surveyed for birds except the natural remnant vegetation. Most of the studies investigating the importance of natural vegetation in urban biodiversity conservation have been carried out in the western part of the world (Pautasso *et al.* 2011, Aronson *et al.* 2014), and even though there are numerous studies in south Asian developing countries (Bhagwat & Rutte 2006, Devkota 2013, Mohammad *et al.* 2013, Gopal *et al.* 2018, Sarkar & Mujumdar 2022), these studies are generally lacking from India. Thus, our goal was to explore the bird diversity of natural remnant vegetation in the Pune urban area.

Material and Methods

Study area

Pune city is located on the eastern edge of the Western Ghats; some hill ranges pass through it in a north-south direction. The current study was conducted at a natural remnant vegetation patch (9.71 ha) at Pashan Lake *(Figure 1)*. This remnant patch contains both native and exotic plant species *(Figure 2)*. Native tree species recorded are *Acacia nilotica, Acacia polyacantha, Pongamia pinnata, Phoenix sylvestris, Dalbergia sissoo, Dalbergia lanceolaria, Bombax ceiba, Ficus religiosa, Ficus benghalensis, Cordia obliqua, Broussonetia papyrifera, Senna siamea, Morinda pubescens, Azadirecta indica, Zizhipus mauritiana, Syzygium cumini, Albizia procera, Trema orientalis.* Exotic tree species recorded

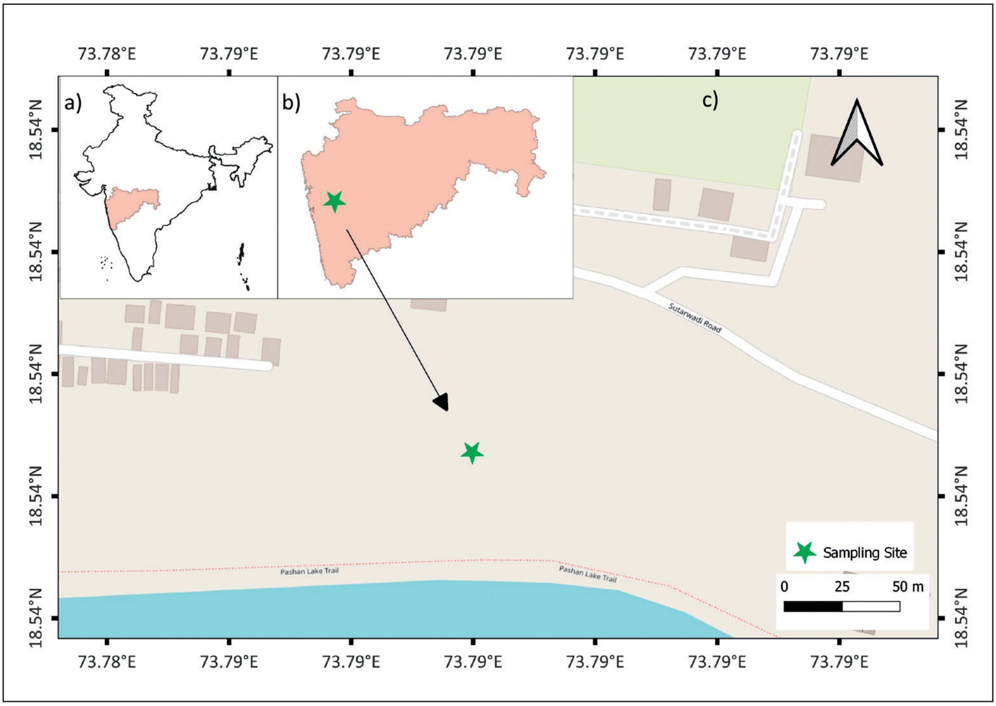


Figure 1. Map of the study area
1. ábra A vizsgált terület térképe

Figure 2. Photograph of natural remnant patch
2. ábra Fénykép a természetes maradvány területről

are *Gliricidia sepium, Samanea saman, Tamarindus indica, Eucalyptus globules, Delonix regia, and Spathodea campanulata.* Invasion of exotic plant species, *Lantana camara* and *Leucaena leucocephala,* is also seen in the remnant patch. The average rainfall is 763 mm; the mean annual temp is 24.3 °C.

Bird survey

The bird survey was conducted between October 2020 and December 2022. The remnant vegetation patch was visited at least once per month. The birds were counted from 7 a.m. to 11 a.m. and from 4 p.m. to 6 p.m. The remnant patch was visited for at least an hour. The entire patch of the natural remnant (9.71ha) was surveyed at each visit by walking through the site and along the edges. Birds were photographed with a Nikon Coolpix B600 and observed with Olympus 10–50 DPS I binoculars. For the identification of birds, we used the field guides of Ali (2002) and Grimmett *et al.* (2011). For nomenclature, we followed Praveen *et al.* (2016), and the food preference of birds was extracted from Ali (2002). All the birds recorded were categorised into four foraging guilds: insectivores, predators, herbivores, and omnivores. Bird information about habitat specialisation, current population trends, and migratory status was taken from the report "State of India's Birds" (SoIB 2020).

Results

We recorded 65 species of birds during the study *(Table 1)*. Omnivores were dominant (32 species), followed by insectivores (12 species), predators (11 species), and herbivores (8 species) *(Table 1)*. Most of the species recorded during the study were residents (58 species), and 7 species were migrants (local migrant: – 4, long-distance migrant: 3). Out of the 65 species recorded at the study site, 17 species were habitat specialists, of which 16 were woodland dwellers (SoIB 2020) *(Table 1)*. Current population trend analysis of recorded species shows that, out of 65 species, the population of 14 species is declining (SoIB 2020). Spotted Dove *Spilopelia chinensis,* Yellow-legged Green Pigeon *Treron Phoenicopterus,* Grey-bellied Cuckoo *Cacomantis passerines,* Common Hawk Cuckoo *Hierococcyx varius,* Black-winged Kite *Elanus caeruleus,* Oriental Honey Buzzard *Pernis ptilorhynchus,* White-cheeked Barbet *Psilopogon viridis*, Ashy Drongo *Dicrurus leucophaeus,* Thick-billed Flowerpecker *Dicaeum agile,* Forest Wagtail *Dendronanthus indicus,* Puff-throated Babbler *Pellorneum ruficeps,* Chestnut-tailed Starling *Sturnia malabarica,* Malabar Whistling Thrush *Myophonus horsfieldii,* Orange-headed Thrush *Geokichla citrina,* Indian Blackbird *Turdus simillimus* were some of the bird species recorded in the natural remnant site.

Discussion

Birds use land cover characteristics as important cues when choosing their habitat (Cody 1981). Habitat preference of birds is influenced by the density and diversity of plant species, the number and percentage of native flora and the amount of anthropogenic disturbance (Mills *et al.* 1989, Chamberlain *et al.* 2007). Previous studies have shown that cemeteries (Čanády & Mošanský 2017, Löki *et al.* 2019) and sacred sites (Devkota 2013, Gopal *et al.* 2018, Sarkar & Mujumdar 2022) are crucial habitats for sensitive and threatened species as well as significant areas for biodiversity conservation in the urban environment. Areas such as natural remnants, cemeteries and sacred sites act as habitat islands for many rare and native species in urban areas (Bhagwat & Rutte 2006). Birds can be seen in all the microhabitats in urban landscapes, often abundant in areas with suitable survival conditions (Cody 1981, Veech *et al.* 2010).

In this study, we recorded 65 bird species in a single natural vegetation patch that hosts higher richness than 20 smaller green spaces (artificial gardens and parks) in the same city (Choudaj & Wankhade 2022). The rare bird species recorded at the natural remnant site were absent from survey conducted in gardens and parks. Vegetation is the primary factor in habitat selection of birds in the urban environment; birds benefit from the diversity of native plants, which may explain the higher species richness in our study (Chace & Walsh 2006, Choudaj & Wankhade 2022).

According to the "State of India's Birds report', hundreds of bird species in India are in decline. Raptors, migratory seabirds and habitat specialists have been the most affected birds in the past decades due to habitat destruction, hunting and pet trade. Current annual trends were estimated for 146 bird species, of which 80% are declining, with almost 50% declining strongly (SoIB 2020). In Pune, due to urbanisation, the richness of rare and habitat-specific

Table 1. The bird species recorded in the natural remnant at Pashan lake with their common and scientific name, feeding guild (O – omnivore, I – insectivore, H – herbivore, P – predator), habitat specialisation (G – generalist, S – specialist) and global population trend (↓ – declining, ↑ – increasing, → – stable, ? – uncertain), migratory status (R – resident, LM – local migrant, LD – long distance migrant)

1. táblázat A Pashán-tónál található természetes maradványban feljegyzett madárfajok angol és tudományos nevükkel, táplálkozási guilddel (O – mindenevő, I – rovarevő, H – növényevő, P – ragadozó), élőhely specializációval (G – generalista, S – specialista) ill. globális populációs trend (↓ – csökkenő, ↑ – növekvő, → – stabil, ? – bizonytalan), vonulási típus (R – állandó, LM – rövidtávú vonuló, LD – hosszútávú vonuló)

	Common Name	**Scientific Name**	**Food Habit**	**Habitat specialization**	**Current population trend**	**Migratory Status**
1	Rock Pigeon	*Columba livia*	H	**G**	↑	**R**
2	Spotted Dove	*Spilopelia chinensis*	H	**G**	→	**R**
3	Laughing Dove	*Spilopelia senegalensis*	H	**G**	**?**	**R**
4	Yellow-legged Green Pigeon	*Treron phoenicopterus*	H	**G**	↑	**R**
5	Greater Coucal	*Centropus sinensis*	P	**G**	↑	**R**
6	Asian Koel	*Eudynamys scolopaceus*	O	**G**	↑	**R**
7	Grey-bellied Cuckoo	*Cacomantis passerinus*	I	**G**	?	**R**
8	Common Hawk Cuckoo	*Hierococcyx varius*	I	**S**	↓	**R**
9	Red-wattled Lapwing	*Vanellus indicus*	P	**G**	↓	**R**
10	Black-winged Kite	*Elanus caeruleus*	P	**S**	↓	**R**
11	Oriental Honey-buzzard	*Pernis ptilorhynchus*	O	**S**	↓	**R**
12	Shikra	*Accipiter badius*	P	**G**	→	**R**
13	Black Kite	*Milvus migrans*	P	**G**	**?**	**R**
14	Spotted Owlet	*Athene brama*	P	**G**	**?**	**R**
15	Indian Grey Hornbill	*Ocyceros birostris*	O	**G**	**?**	**R**
16	Coppersmith Barbet	*Psilopogon haemacephalus*	H	**S**	**?**	**R**
17	White-cheeked Barbet	*Psilopogon viridis*	H	**G**	**?**	**R**
18	Green Bee-eater	*Merops orientalis*	I	**G**	↓	**R**
19	White-throated Kingfisher	*Halcyon smyrnensis*	P	**G**	↓	**R**
20	Alexandrine Parakeet	*Psittacula eupatria*	H	**S**	↑	**R**
21	Rose-ringed Parakeet	*Psittacula krameri*	H	**G**	→	**R**
22	Small Minivet	*Pericrocotus cinnamomeus*	I	**S**	↓	**R**
23	Eurasian Golden Oriole	*Oriolus oriolus*	O	**G**	**?**	**LM**
24	Common Iora	*Aegithina tiphia*	O	**S**	↓	**R**
25	Black Drongo	*Dicrurus macrocercus*	O	**G**	↓	**R**
26	Ashy Drongo	*Dicrurus leucophaeus*	O	**S**	**?**	**LM**
27	White-browed Fantail	*Rhipidura aureola*	I	**S**	**?**	**R**
28	Long-tailed Shrike	*Lanius schach*	P	**G**	↓	**R**

	Common Name	Scientific Name	Food Habit	Habitat specialization	Current population trend	Migratory Status
29	Rufous Treepie	*Dendrocitta vagabunda*	O	G	?	R
30	House Crow	*Corvus splendens*	O	G	→	R
31	Jungle Crow	*Corvus macrorhynchos*	O	G	→	R
32	Indian Paradise-flycatcher	*Terpsiphone paradise*	I	S	?	LM
33	Thick-billed Flowerpecker	*Dicaeum agile*	O	G	?	R
34	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos*	O	G	↑	R
35	Purple-rumped Sunbird	*Leptocoma zeylonica*	O	G	?	R
36	Purple Sunbird	*Cinnyris asiaticus*	O	G	→	R
37	Baya Weaver	*Ploceus philippinus*	O	G	↓	R
38	Scaly-breasted Munia	*Lonchura punctulata*	H	G	?	R
39	House Sparrow	*Passer domesticus*	O	G	→	R
40	Forest Wagtail	*Dendronanthus indicus*	P	S	↓	LD
41	Cinereous Tit	*Parus cinereus*	I	G	?	R
42	Ashy Prinia	*Prinia socialis*	I	G	?	R
43	Plain Prinia	*Prinia inornata*	O	G	?	R
44	Grey breasted Prinia	*Prinia hodgsonii*	O	G	?	R
45	Common Tailorbird	*Orthotomus sutorius*	O	G	↑	R
46	Blyth's Reed Warbler	*Acrocephalus dumetorum*	I	G	?	LD
47	Red-whiskered Bulbul	*Pycnonotus jacosus*	O	G	?	R
48	Red-vented Bulbul	*Pycnonotus cafer*	O	G	→	R
49	Greenish Warbler	*Phylloscopus trochiloides*	P	S	?	LM
50	Yellow-eyed Babbler	*Chrysomma sinense*	O	G	↓	R
51	Oriental White-eye	*Zosterops palpebrosus*	O	G	?	R
52	Puff-throated Babbler	*Pellorneum ruficeps*	P	S	?	R
53	Large Grey Babbler	*Argya malcolmi*	O	G	?	R
54	Brahminy Starling	*Sturnia pagodarum*	O	G	?	R
55	Chestnut-tailed Starling	*Sturnia malabarica*	O	S	?	R
56	Common Myna	*Acridotheres tristis*	O	G	→	R
57	Jungle Myna	*Acridotheres fuscus*	O	G	↓	R
58	Indian Robin	*Saxicoloides fulicatus*	P	G	?	R
59	Oriental Magpie Robin	*Copsychus saularis*	O	G	→	R
60	Tickell's Blue Flycatcher	*Cyornis tickelliae*	I	S	?	R
61	Red-breasted Flycatcher	*Ficedula parva*	I	S	?	LD
62	Pied Bushchat	*Saxicola caprata*	I	G	?	R
63	Malabar Whistling Thrush	*Myophonus horsfieldii*	O	G	?	R
64	Orange-headed Thrush	*Geokichla citrina*	O	S	?	R
65	Indian Blackbird	*Turdus simillimus*	O	G	?	R

birds is declining in all the habitats (Ingalhalikar *et al.* 2001), including the academic campus (Nerlekar *et al.* 2016, Choudaj & Wankhade 2021a) and hills (Choudaj & Wankhade 2021b). The presence of rare habitat specialists and threatened species in natural remnants highlights the importance of this habitat type in the sustainability of urban biodiversity.

Though we observed the invasion of exotic plant species, *Leucaena leucocephala* and *Lantana camara* in the natural remnant site, it still retains higher avian richness than gardens and parks. The following reasons could contribute to this: this site is inaccessible to the public and it has significant amount of undergrowth of vegetation and aerial leaf litter. Many arthropod species flourish in aerial leaf litter, which serves as an important foraging resource for many insectivorous bird species (Mansor *et al.* 2019). In this study, we observed insectivorous species such as Forest Wagtail *Dendronanthus indicus,* Puff-throated Babbler *Pellorneum ruficeps,* Malabar Whistling Thrush *Myophonus horsfieldii,* Orange-headed Thrush *Geokichla citrina* exploiting leaf litter. The absence of these species in gardens and urban parks may be due to the regular cleaning of leaf litter and the presence of artificial grass, which is a potential threat to ground-feeding birds (Sánchez-Sotomayor *et al.* 2022).

Birds are vulnerable to urbanisation and species richness typically drops in urban centres, leading to generalist and urban-adapted species assemblages (Lim & Sodhi 2004, Chace & Walsh 2006, Devictor *et al.* 2007, van Heezik *et al.* 2008). Many species rely on isolated, remnant natural vegetation for food and shelter, and the presence of this habitat type has been linked to increased bird diversity (Sewell & Catterall 1998, Chace & Walsh 2006, Evans *et al.* 2009).

Most of the cities are established in areas of rich biodiversity. Natural vegetation became fragmented due to extensive development for urbanisation and scattered in small patches. Small, isolated patches are given lower priority in conservation planning because of a belief that they have limited ecological significance (Tulloch *et al.* 2016). The global analysis demonstrates that biodiversity declines when small, isolated patches are ignored, along with numerous species that are unique to particular environments (Wintle *et al.* 2019). Therefore, we advocate prioritising the preservation of natural remnants in urban environments, which will benefit not only birds but also other species that use this type of habitat. The role of natural vegetation in biodiversity has been well studied and understood in developed countries (Western Europe and the United States of America) (Pautasso *et al.* 2011, Aronson *et al.* 2014), more studies are needed in other parts of the world, especially in developing countries. Managers and wildlife planners need to understand the significance of such habitats from the perspective of biodiversity protection.

Acknowledgements

We thank the University Grants Commission of India and the Council of Scientific and Industrial Research India for providing a research fellowship to both authors to complete their PhD. We are indebted to the Department of Zoology, Savitribai Phule Pune University Pune; Department of Biodiversity, Abasaheb Garware College; Department of Zoology, Modern College providing research facilities. Our special thanks go to the reviewers for their valuable suggestions and comments.

References

Ali, S. 2002. The Book of Indian birds, 13th ed. – Oxford University Press, London

Aronson, M., La Sorte, F., Nilon, C. Katti, M., Goddard, M., Lepczyk, C., Warren, P., Williams, N., Cilliers, S., Clarkson, B., Dobbs, C., Dolan, R., Hedblom, M., Klotz, S., Louwe Kooijmans, J., Kühn, I., MacGregor-Fors, I., McDonnell, M., Mörtberg, U. & Winter, M. 2014. A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers. – Proceedings of the Royal Society B: Biological Sciences 281: 20133330. DOI: 10.1098/rspb.2013.3330

Bhagwat, S. A. & Rutte, C. 2006. Sacred groves: potential for biodiversity management. – Frontiers in Ecology and the Environment 4(10): 519–524. DOI: 10.1890/1540-9295(2006)4[519: SGPFBM]2.0.CO;2

Butsch, C., Kumar, S., Wagner, P., Mareike, K., Kantakumar, L., Bharucha, E., Schneider, K. & Kraas, F. 2017. Growing 'Smart'? Urbanization Processes in the Pune Urban Agglomeration. – Sustainability 9(12): 2335. DOI: 10.3390/su9122335

Čanády, A. & Mošanský, L. 2017. Public cemetery as a biodiversity hotspot for birds and mammals in the urban environment of Kosice city (Slovakia). – Zoology and Ecology 27(3–4): 185–195. DOI: 10.1080/21658005.2017.1366024

Chace, J. F. & Walsh, J. J. 2006. Urban effects on native avifauna: a review. – Landscape and Urban Planning 74(1): 46–69. DOI: 10.1016/j.landurbplan.2004.08.007

Chamberlain, D. E., Gough, S., Vaughan, H., Vickery, J. A. & Appleton, G. F. 2007. Determinants of bird species richness in public green spaces. – Bird Study 54(1): 87–97. DOI: 10.1080/00063650709461460

Choudaj, K. & Wankhade, V. 2021a Changed avian assemblage of Savitribai Phule Pune university campus in last four decades. – Journal of Threatened Taxa 13(3): 17990–17998. DOI: 10.11609/jott.4769.13.3.17990-17998

Choudaj, K. & Wankhade, V. 2021b Reduction in avian diversity due to exotic tree plantations on the native savannas of Pune City, India. – Tropical Ecology 62: 499–507. DOI: 10.1007/s42965-021-00158-1

Choudaj, K. & Wankhade, V. 2022. Study of the interrelationship between woody plants and birds in Pune urban area, insights on negative impacts of exotic plants. – Tropical Ecology. DOI: 10.1007/s42965-022-00269-3

Cody, M. L. 1981. Habitat selection in birds: the roles of vegetation structure, competitors, and productivity. – BioScience 31(2): 107–113. DOI: 10.2307/1308252

Devictor, V., Julliard, R., Couvet, D., Lee, A. & Jiguet, F. 2007. Functional homogenization effect of urbanization on bird communities. – Conservation Biology 21(3): 741–751. DOI: 10.1111/j.1523-1739.2007.00671.x

Devkota, M. P. 2013. Sacred groves as sanctuaries for Mistletoe Conservation in Kathmandu Valley. – In: Lowman, M., Devy, S. & Ganesh, T. (eds.) Treetops at Risk: Challenges of Global Canopy Ecology and Conservation. – Springer, New York, pp. 405–414. DOI: 10.1007/978-1-4614-7161-5_43

Evans, K. L., Newson, S. E. & Gaston, K. J. 2009. Habitat influences on urban avian assemblages. – Ibis 151(1): 19–39. DOI: 10.1111/j.1474-919X.2008.00898.x

Fernández-Juricic, E. 2000. Local and regional effects of pedestrians on forest birds in a fragmented landscape. – The Condor 102(2): 247–255. DOI: 10.1093/condor/102.2.247

Gopal, D., von der Lippea, M. & Kowarik, I. 2018. Sacred sites as habitats of culturally important plant species in an Indian megacity. – Urban Forestry & Urban Greening 32: 113–122. DOI: 10.1016/j.ufug.2018.04.003

Grimmett, R., Inskipp, C. & Inskipp, T. 2011. Birds of the Indian Subcontinent. 2nd ed. – Oxford University Press & Christopher Helm, London

Ingalhalikar, S., Purandare, R., Nalavade, S. & Dhole, S. 2001. Bird diversity changes of Pune urban area. – Journal of Ecological Society 13–14: 59–70.

Lim, H. & Sodhi, N. 2004. Responses of avian guilds to urbanisation in a tropical city. – Landscape and Urban Planning 66(4): 199–215. DOI: 10.1016/S0169-2046(03)00111-7

Löki, V., Deák, B., Lukács, A. B. & Molnár, A. 2019. Biodiversity potential of burial places – a review on the flora and fauna of cemeteries and churchyards. – Global Ecology and Conservation 18: e00614. DOI: 10.1016/j.gecco.2019.e00614

Mansor, M. S., Rozali, F. Z., Abdullah, N. A., Nor, S. M. & Ramli, R. 2019. How important is aerial leaf litter for insectivorous birds foraging in a Malaysian tropical forest? – Global Ecology and Conservation 20: e00722. DOI: 10.1016/j.gecco.2019.e00722

Mohamad, N. H. N., Idilftri, S. & Thani, S. K. S. O. 2013. Biodiversity by design: the attributes of ornamental plants in urban forest parks. – Procedia – Social and Behavioral Sciences 105: 823–839. DOI: 10.1016/j.sbspro.2013.11.085

Mills, G. S., Dunning, J. B. & Bates, J. M. 1989. Effects of urbanization on breeding bird community structure in southwestern desert habitats. – Condor 91(2): 416–428. DOI: 10.2307/1368320

Nagendra, H. & Gopal, D. 2010. Street trees in Bangalore: Density, diversity, composition and distribution. – Urban Forestry & Urban Greening 9(2): 129–137. DOI: 10.1016/j.ufug.2009.12.005

Nagendra, H. 2016. Nature in the City: Bengaluru in the Past, Present and Future. – Oxford University Press, New Delhi. DOI: 10.1093/acprof:oso/9780199465927.001.0001

Nerlekar, A., Warudkar, A., Gowande, G., Salve, S., Raut, A., Patankar, S. & Nalavade, S. 2016. A review of the faunal diversity of the Fergusson College campus, Pune, India. – Zoos‘ Print Magazine 31: 4–25.

Parris, K. M. 2016. Ecology of Urban Environments. – Wiley Blackwell, Oxford

Pautasso, M., Bohning-Gaese, K., Clergeau, P., Cueto, V. R., Dinetti, M., Fernández-Juricic, E., Kaisanlahti-Jokimäki, M., Jokimäki, J., McKinney, M. L., Sodhi, N. S., Storch, D., Tomialojc, L., Weisberg, P. J., Woinarski, J., Fuller, R. A. & Cantarello, E. 2011. Global macroecology of bird assemblages in urbanized and semi-natural ecosystems. – Global Ecology and Biogeography 20(3): 426–436. DOI: 10.1111/j.1466-8238.2010.00616.x

Praveen, J., Jayapal, R. & Pittie, A. 2016. A checklist of the birds of India. – Indian Birds 11(5–6): 113–172.

Punalekar, S., Mahajan, D. & Kulkarni, D. K. 2010. Impact of exotic tree species on the native vegetation of Vetal Hill, Pune. – Indian Journal of Forestry 33(4): 549–554. DOI: 10.54207/bsmps1000-2010-RH552C

Ruas, R., Costa, L. & Bered, F. 2022. Urbanization driving changes in plant species and communities – A global view. – Global Ecology and Conservation 38: e02243. DOI: 10.1016/j.gecco.2022.e02243

Sarkar, A. & Mazumdar, S. 2022. Sacred green spaces in semi-urban areas sustain more birds than its adjacent areas: A study from lower Gangetic plains, West Bengal, India. – Ornis Hungarica 30(1): 97–112. DOI: 10.2478/orhu-2022-0007

Sewell, S. R. & Catterall, C. P. 1998. Bushland modification and styles of urban development: their effects on birds in south-east Queensland. – Wildlife Research 25(1): 41–63. DOI: 10.1071/WR96078

SoIB. 2020. State of India's Birds factsheet. – https://www.stateofindiasbirds.in/species

United Nations, Department of Economic and Social Affairs, Population Division. 2018. The World's Cities in 2018. – The World's Cities in 2018 – Data Booklet (ST/ESA/ SER.A/417) 34. New York, United Nations

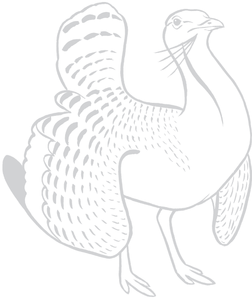
Tulloch, A. I. T., Barnes, M. D., Ringma, J., Fuller, R. A. & Watson, J. E. M. 2016. Understanding the importance of small patches of habitat for conservation. – Journal of Applied Ecology 53: 418–429. DOI: 10.1111/1365-2664.12547

United Nations, Department of Economic and Social Affairs, Population Division. 2019. World Urbanization Prospects: The 2018 Revision (ST/ESA/SER.A/420). – New York, United Nations

van Heezik, Y., Smyth, A. & Mathieu, R. 2008. Diversity of native and exotic birds across an urban gradient in a New Zealand city. – Landscape and Urban Planning 87(3): 223–232. DOI: 10.1016/j.landurbplan.2008.06.004

Veech, J. A., Small, M. F. & Baccus, J. T. 2010. The effect of habitat on the range expansion of a native and an introduced bird species. – Journal of Biogeography 38(1): 69–77. DOI: 10.1111/j.1365-2699.2010.02397.x

Wintle, B. A., Kujala, H., Whitehead, A., Cameron, A., Veloz, S., Kukkala, A., Moilanen, A., Gordon, A., Lentini, P. E., Cadenhead, N. C. R., Bekessy, S. A. 2019. Global synthesis of conservation studies reveals the importance of small habitat patches for biodiversity. – Proceedings of the National Academy of Sciences USA 116(3): 909–914. DOI: 10.1073/pnas.1813051115



sciendo

Ornis Hungarica 2023. 31(1): 72–87.
DOI: 10.2478/orhu-2023-0005

Do the barrier islands of the Po Delta constitute an ecological trap for colonising Slender-billed Gulls *Larus genei*?

Roberto G. Valle[1]*, Emiliano Verza[2] & Francesco Scarton[3]

Received: December 29, 2022 – Revised: March 31, 2023 – Accepted: April 01, 2023

Valle, R. G., Verza, E. & Scarton, F. 2023. Do the barrier islands of the Po Delta constitute an ecological trap for colonising Slender-billed Gulls *Larus genei*? – Ornis Hungarica 2023. 31(1): 72–87. DOI: 10.2478/orhu-2023-0005

Abstract The Slender-billed Gull *(Larus genei)* breeds with a scattered distribution on an extensive nesting area, ranging from India and Afghanistan in the East to the Iberian Peninsula in the West, including the Mediterranean and the Black Sea. A number of habitats are used for breeding, such as sand-spits and beaches along coasts and islands of land-locked seas, steppe lakes, but also brackish or freshwater lagoons near river deltas. Sea level rise dramatically affects coastal sites, thus being the greatest threat to the survival of many seabird species, including gulls. This note describes habitat selection, breeding success and causes of failure of Slender-billed Gulls during their colonisation of the northern Po Delta (NE Italy) during 2018–2022. Slender-billed Gulls colonised the northern Po Delta in 2018. Six colonies were found during the study period. Birds used both natural barrier islands and artificial dredge islands. Productivity in the first five years after the colonisation event was zero, mostly due to colony sites being flooded by high tides and storms. If Slender-billed Gulls will switch to nest in nearby fish farms, these could provide plenty of suitable breeding sites, safe from tidal flooding and with very low predation pressure, allowing sufficient productivity. At the moment, Slender-billed Gulls are unsuccessful in colonising the barrier islands of the Po Delta.

Keywords: breeding, drones, habitat selection, productivity, sea level rise

Összefoglalás A vékonycsőrű sirály *(Larus genei)* elszórtan költ egy hatalmas fészkelő területen, India keleti részétől és Afganisztántól az Ibériai-félsziget nyugati részéig, beleértve a Mediterráneumot és a Fekete-tengert. Számos élőhelyet használnak költésre, például homokpadokat, tengerpartokat, beltengerek szigeteit, sztyeppei tavakat, sós vagy édesvízi lagúnákat a folyódelták közelében. A tengerszint emelkedése drámaian érinti a part menti területeket, így ez jelenti a legnagyobb veszélyt számos tengeri madárfaj, köztük a sirályok túlélésére. Ez a cikk a vékonycsőrű sirályok élőhely-kiválasztását, költési sikerét és kudarcának okait írja le a 2018–2022 közötti időszakban, a Pó-delta északi részén (Észak-Olaszország) való kolonizációjuk során. A vékonycsőrű sirályok 2018-ban kolonizálták a Pó-delta északi részét. A vizsgálati időszak alatt a felmérők hat telepet találtak. A madarak a költéshez természetes gátszigeteket és mesterséges kotrószigeteket egyaránt használtak. A megtelepedéstől számított öt évben a költési siker nulla volt, főként a dagály és viharok által elárasztott költőhelyek miatt. A vékonycsőrű sirályok a közeli halgazdaságok területén találhatnának megfelelő költőhelyet, ezek ugyanis védettek az árapály-áradásoktól, és a predációs nyomás is nagyon alacsony, a körülmények megfelelő költéssikert tennének lehetővé. Jelenleg a vékonycsőrű sirályok sikertelenek a Pó-delta kolonizálásában.

Kulcsszavak: költés, drónok, élőhely kiválasztása, termékenység, tengerszint emelkedés

[1] *Rialto, San Polo 571, 30125 Venice, Italy*
[2] *Via F.llii Cairoli, 38, 45100 Rovigo, Italy*
[3] *Via Franchetti 192, I-31022 Preganziol (TV), Italy*
** corresponding author, e-mail: robertovalle@libero.it*

Introduction

The Slender-billed Gull *(Larus genei)* breeds with a scattered distribution covering an extensive nesting area, ranging from India and Afghanistan in the East to the Iberian Peninsula in the West, including the Mediterranean and the Black Sea (BirdLife International 2022). The estimated global population size of the species is 120,000–140,000 individuals (Wetlands International 2022) with an uncertain trend. Overall, about 63,000 individuals are estimated to reside in Europe, where the species is decreasing and classified as Vulnerable (BirdLife International 2021). A number of habitats are used for breeding, such as sand-spits and beaches along coasts and islands of land-locked seas, steppe lakes, but also brackish or freshwater lagoons near river deltas (Keller *et al.* 2020, BirdLife International 2022).

The population inhabiting Italy, where the species started breeding in 1976 with 34 pairs in Sardinia, amounted to 3,000–5,000 pairs during 2006–2012 (Brichetti & Fracasso 2018), with a patchy distribution pattern including breeding sites in Sardinia and along the Adriatic coastline, both in the south (Apulia) and in the north (Emilia-Romagna). More recent estimates give a figure of 1,500–2,000 pairs, with a declining trend (De Faveri 2022).

Along the northern Adriatic coastline (NE Italy), the Slender-billed Gull traditionally bred on brackish lagoons (Valli di Comacchio), saltpans (Saline di Cervia) and fish farms (Valle Bertuzzi) (Brichetti & Fracasso 2018). From 2015, Slender-billed Gulls has started to spread north, colonising some recently built artificial marsh islands in the open lagoons of the southern Po Delta, south of the Po di Goro River, in 2017. From 2018, they spread further northward, settling on barrier islands of the northern Po Delta in the Veneto Region (Valle *et al*. 2022), which had never been used before by the species (Scarton *et al*. 2005, 2018).

This study describes habitat selection, breeding success and causes of failure of Slender-billed Gulls during their colonisation of the northern Po Delta during the 2018–2022 period.

Material and Methods

Study Site

We conducted the breeding bird surveys in 2018–2022 in the wetlands of the Po Delta located north of the Po di Goro river (hereafter "northern Po Delta"), in the Veneto Region, between the mouth of Adige river (45°09' N, 12°20' E) to the north and the Po di Goro River (44°47' N, 12°24' E) to the south, along a 50 km long section of coastline. Apart from the Po river and its branches, the Po Delta is characterised by a number of shallow brackish lagoons separated from the mainland by twenty-four fish farms and by thirty barrier islands (Day *et al.* 2019).

One important morphological feature of the Northern Adriatic is that it experiences high tides of more than 1 m as compared to most of the Mediterranean Sea where the mean tidal range does not exceed 20–30 cm. The combined effects of high tides, storm surge and the seiche phenomenon (i.e. free oscillations of the water body caused by winds, which can persist for several days) produce in the northern Adriatic the highest sea level extremes of the whole Mediterranean (Medvedev *et al*. 2020, Šepić *et al.* 2022). Moreover, recent studies show that the relative sea level rise is the major driver of the increase in the frequency of floods observed over the last century (Ferrarin *et al.* 2022). Extreme high tides occurring in late spring may have disastrous effects on the reproductive success of waders and seabirds nesting in the Gulf of Venice at saltmarshes, dredge islands and other low-elevation sites such as barrier islands (Scarton & Valle 2015). Tidal levels used in the present paper refer to a tidal gauge located in the lagoon of Venice, about 40 km far from the study site (Comune di Venezia 2022).

The community of breeding gulls and terns of the northern Po Delta is one of the largest in the Mediterranean, with ca. 7,000 pairs in 2015–2018 (Valle & Verza 2020). Due to its importance for birds, the area is listed as a Special Protection Area (IT3270023 – Delta del Po) under the European Union 147/09 Birds Directive.

We studied Slender-billed Gulls as part of a long-term monitoring program of breeding waterbirds (Scarton *et al.* 2005, 2018, Valle & Verza 2020). The barrier islands of the northern Po Delta are historically used for breeding by a few waterbird species: Eurasian Oystercatcher *Haematopus ostralegus*, Kentish Plover *Charadrius alexandrinus*, Yellow-legged Gull *Larus michahellis*, and Little Tern *Sternula albifrons* (Valle & Scarton 1999), but some species, other than the Slender-billed Gull, recently settled: Pied Avocet *Recurvirostra avosetta*, Sandwich Tern *Thalasseus sandvicensis*, and Common Tern *Sterna hirundo* (Valle & Verza 2020). Predators of eggs, chicks or adults include Red Foxes *Vulpes vulpes*, Marsh Harriers *Circus aeruginosus*, Montagu's Harriers *Circus pygargus*, and Yellow-legged Gulls (Valle & Scarton 1999).

Field data collection

In each year, all the barrier islands along with the lagoons laying behind were surveyed by boat and by drone for nesting colonies. Once a colony was discovered, we used small drones to count nesting pairs, to assess habitat selection and to estimate the reproductive success (Valle & Scarton 2021a, 2021b). Colonies were monitored during the peak breeding season (mid-May – mid-July) by weekly drone flights from laying to fledging or failure. Surveys took place between 08:30 and 17:30 hours (but diurnal periods of extreme temperatures, such as early morning or noon, were avoided), avoiding days with unusually high tides, strong winds and rains. All apparently active nests, i.e. those containing eggs and/or chicks, were counted. The number of breeding pairs was assumed to be the same as the number of active nests. Nests were mapped flying at elevations above ground level (AGL) higher than the agitation distance, i.e. adults opening wings in response to low AGL overflights known for the species (Valle & Scarton 2018). According to the current recommendations (Hodgson & Koh 2016), the drone was launched at least 150 m from the colony, in order to minimise disturbance to birds. The drone reached the vertical point of the colony through a lawn-mower flight pattern, flying 70 m AGL. During the next phase, the drone was slowly driven once more through a lawn-mower flight pattern to an altitude of 10 m AGL, which allowed the detection of incubating birds upon post-processing, and it slowly flew over the colony at a speed of 10 km/h. During the low-AGL survey, the different bird species

Figure 1. Close-up drone imagery during low-AGL flight aimed at locating clutches of different species in a mixed colony of Slender-billed Gulls and Sandwich Terns (Po Delta, NE Italy in 2020). Lack of disturbance by drone intrusion on Slender-billed Gulls can be inferred by the apparently indifferent chicks and adults in the foreground

1. ábra Közeli drónfelvételek alacsony AGL-szintű repülés közben, amelyek célja a vékonycsőrű sirályok és a kenti csérek alkotta vegyes kolóniájában költő fajok fészekaljainak azonosítása (Pódelta, ÉK-Olaszország 2020-ban). A drónok behatolása a vékonycsőrű sirályokat nem zavarta, amit az előtérben látható közömbös fiókák és felnőttek mutatnak

were identified on nest *(Figure 1)*. This allowed us to avoid serial ground visits except for elevation above water level (AWL) estimation, which was assessed after site abandonment by the nesting adults. Breeding success was categorised according to Valle and Scarton 2021b. Nests were categorised as (1) active (presence of eggs) or successful (presence of hatchlings) or (2) unsuccessful, when a) predated, if beak marks or yolk were found on shell, b) flooded, i.e. eggs found wet or out of nest cups after exceptionally high tides, c) deserted or infertile (eggs found after 28 days of incubation), or d) disappeared; when the cause of egg loss could not be univocally determined, e.g. when eggs disappeared following violent rainfall thus being possibly washed away. During drone surveys, the number of hatchlings was recorded for successful nests. Maximal flight time was <5 min. During the drone flight, an assistant researcher observed the colony from afar to exclude possible predation of unattended clutches and/or chicks by aerial predators (Valle & Scarton 2021a, 2021b).

Image Processing

Drone counts were performed on a personal computer using DotDotGoose's count tool v.1.3.0 (Ersts 2019) on images directly shot in the field or selected frames obtained from videos automatically stitched together using ICE (Microsoft's Image Composite Editor,

Figure 2. Upper panel: mixed colony of Slender-billed Gulls (orange line) and Sandwich Terns (black lines) in a drone image, late May 2020. Slender-billed Gulls are scattered along the shore facing the lagoon, nests being located within a few meters from the tideline. Co-present Sandwich Terns occupy the inner part of the barrier island (black encircling line). The wrecked tree trunk in the lower, right quadrant, between Sandwich Terns and Slender-billed Gulls (green arrow), is also visible in the Google Earth image in the lower panel. Lower panel: Google Earth imagery (April 2020) of the 2020 colony site of Slender-billed Gulls (orange line) and Sandwich Terns (black lines) on a barrier island in the Po Delta. The same barrier island also hosted a colony of Slender-billed Gulls both in 2018 (mixed with Sandwich Terns) and 2021 (alone)

2. ábra Felső panel: vékonycsőrű sirályok (narancssárga vonal) és kenti csérek (fekete vonalak) vegyes kolóniája drónképen, 2020 május végén. A vékonycsőrű sirályok a lagúnával szemben elszórtan helyezkednek el a part mentén, a fészkek néhány méteren belül találhatók a dagályvonaltól. A szintén jelenlevő kenti csérek a gátsziget belső részét foglalják el (fekete körvonal). Az alsó, jobb oldali kvadránsban, a kenti csér és a vékonycsőrű sirály között (zöld nyíl) található összetört fatörzs az alsó panelen lévő Google Earth képen is látható. Alsó panel: Google Earth-képek (2020 április) a 2020-as vékonycsőrű sirályok (narancssárga vonal) és kenti csér (fekete vonalak) kolóniájáról a Pó-delta egyik gátszigetén. Ugyanez a gátsziget 2018-ban (a kenti csérekkel vegyesen) és 2021-ben (egyedül) a vékonycsőrű sirály kolóniának is otthont adott release 2.0; www.microsoft.com). In the post-processing phase, a grid (10 × 10 m) was overlaid on drone imagery *(Figure 2)*, individual nests were assigned a number and counted, their fate was assessed and habitat parameters were measured grid cell-by-grid cell on serial (weekly) imagery (Valle & Scarton 2021b). Habitat choice was investigated at the nest site level, superimposing an arbitrary grid of 10 × 10 m quadrats (*sensu* Scarton & Valle 2020) in a radius of 100 m from the centre of the colony, on the drone imagery of the study islands using the free software QGIS (release 3.12.1; www.qgis.org; *Figure 2*). Each quadrat was characterised, when applicable, for the presence-absence and number of nests of Slender-billed Gulls and for the following biotic and abiotic parameters: 1–5)% of the quadrat covered by vegetation, bare sand, water surface (the latter measured both inside the islets for tidal pools and surrounding the island, i.e. the open lagoon and sea), and wrecked material. Other parameters include: 6) location, classified as “central” (the quadrat was separated from the water edge by at least another quadrat) or “peripheral” (the quadrat was at the water edge), 7–9) distance from the sea and from the lagoon, height of ground above the water level (AWL), the latter being visually estimated in four classes 0–10, 11–20, 21–30, 31–40 cm. Finally, the presence of nests of other species was also recorded. All measurements were performed by two observers who were unaware of each other’s results. We planned to assess both hatching success (number of hatched chicks per nest attempt) and fledging success (number of chicks that survived to three weeks of age per nesting attempt). These surveys, which were planned to be carried out up to three weeks of age, permit only a conservative estimate of productivity, but we chose not to fly over older chicks that would be capable of flying away in response to drone intrusion (pers. obs.).

Statistics

Statistical analysis was conducted using SPSS statistics, v.20. Categorical data are presented as percentages and continuous data as mean $\pm$ 1 standard deviation. Variables were square root- or arcsin – square root-transformed as necessary to meet the assumptions of normality of the parametric tests. All tests are two-tailed, and a value of $P < 0.05$ was considered significant. Differences in count data were tested by means of a χ^2 test, those in mean values were tested using unpaired t-test. Pearson correlation coefficient was used to test correlation among variables. We investigated the relationships of the biotic and abiotic variables of quadrats with nest presence – absence by means of logistic regression. We conducted correlation analyses (Spearman’s test) to reduce collinearity and the number of variables used in multivariate analyses; we retained the variable perceived as more biologically important among two or more of strongly inter-correlated variables ($r > 0.60$), since they may be considered as estimates of a single underlying factor (Sokal & Rohlf 1981). The strength of the association between Slender-billed Gulls and other nesting birds was studied using the *phi* association coefficient (Krebs 1978). This coefficient may range between –1 (complete avoidance) and +1 (complete association). The significance for each combination of two species was examined by 2 × 2 Fisher exact probability test.

Results

The first colony of Slender-billed Gulls (54 nests) settling in the northern Po Delta was found in mid-June 2018 on a barrier island, possibly as a replacement attempt by birds from a colony recently destroyed by heavy predation, located a few km further south in the southern Po Delta. Birds settled on the central part of the barrier island (1,150 m long and 70 m wide for overall 10.2 ha), connected with the mainland through a long and narrow embankment and separated from the mainland only by a narrow channel *(Figure 3)*.

They were rapidly joined by 224 pairs of Sandwich Terns possibly from the same above-mentioned site, where a colony of this species has been predated. A colony of Little Terns was found at the northern end of the colony site, but nests of this species were spaced well apart from those of Slender-billed Gulls and Sandwich Terns. Slender-billed Gulls laid 54 clutches (1.8±0.7 eggs per clutch), with a hatching success of 95% (three eggs were crashed in one nest and two more single-egg clutches were deserted) in the first week of July *(Figure 4)*. Nevertheless, none of the chicks fledged, they disappeared, probably due to predation by unknown animals.

No Slender-billed Gulls laid eggs in the study area in the 2019 breeding season, while in May 2020, 276 nests were found in the same barrier island, not far from the site of the

Figure 3. Location (white arrow) of the first colony of Slender-billed Gulls settling on a barrier island in the northern Po Delta (late June 2018). The colony could be reached from the mainland by mammalian predators such as the Red Fox *(Vulpes vulpes)* crossing the narrow channel on the left in the picture and then using the long dike leading to the barrier island.

3. ábra A Pó-delta északi részén található gátszigeten megtelepedő vékonycsőrű sirályok első kolóniájának helye (fehér nyíl) (2018 június vége). A kolóniát a szárazföldről emlős ragadozók, például a vörös róka *(Vulpes vulpes)* a képen bal oldali keskeny csatornán átkelve, majd a gátszigethez vezető hosszú gáttal érhették el

Figure 4. Nests of Slender-billed Gulls on a barrier island of the Po Delta (NE Italy) in early July 2018.
4. ábra Vékonycsőrű sirályok fészkei a Pó-delta egyik gátszigetén (Észak-Olaszország) 2018 július elején

previous year (400 m, though the barrier island had been heavily modified in shape by the winter storms). They were rapidly joined by 891 pairs of Sandwich Terns once more *(Figures 2, 3)*. A large mixed colony of Little Terns (200 pairs), Common Terns (100 pairs) and Avocets (20 pairs), and a few Kentish Plovers was adjacent (but clearly separated from Slender-billed Gulls and Sandwich Terns), whereas a couple of Oystercatcher pairs bred within 100 m. No clutch of Slender-billed Gulls was preyed upon. Eggs started to hatch in the last days of May with a hatching success of 78%, when an extreme high tide of 1.16 m flooded all remaining eggs along with chicks on 4th June.

Only 11 pairs of Slender-billed Gulls laid on the same site in 2021, near a multi-specific colony, but all clutches were quickly preyed upon possibly by Red Foxes.

In 2022, 109 pairs (distributed in two sub-colonies of 83 and 26 nests) settled on two contiguous mounds of bivalve shells, which are relicts of a formerly present dredge island *(Figure 5)*. Breeders were joined by 18 pairs of Sandwich Terns, whereas two pairs of Avocet and one of Oystercatcher laid their eggs before Slender-billed Gull settlement. All clutches were washed away on 25th May *(Figure 6)*.

In the following days, five pairs laid seven eggs (1.4±0.5 eggs per clutch) in a fish farm, settling on remnants of a mound just a few cm above water level. All clutches were washed away due to a rapid increase of water level due to torrential rain.

Figure 5. Google Earth imagery (October 2021) of the 2022 mixed colony site of Slender-billed Gulls (orange arrows) and Sandwich Terns (white arrow) on a barrier island in a lagoon of the Po Delta (NE Italy). The short orange arrow indicates the sub-colony showed in Figure 6.

5. ábra A Google Earth képei (2021 október) a vékonycsőrű sirályok (narancssárga nyilak) és a kenti csér (fehér nyíl) 2022-es vegyes kolóniájáról a Pó-delta lagúnájában (Észak-Olaszország) egy gátszigeten. A rövid narancssárga nyíl az 1. ábrán látható altelepet jelzi

Figure 6. Drone imagery of a sub-colony of Slender-billed Gulls on a dredge island in the Po Delta (NE Italy) in late May 2022, before (left panel) and after (right panel) an extreme high tide.

6. ábra Drónfelvételek a vékonycsőrű sirályok alkolóniájáról a Pó-delta (Észak-Olaszország) kotrási szigetén 2022 májusának végén, szélsőséges dagály előtt (bal oldali panel) és után (jobb panel)

Table 1. Drone-derived imagery-based assessment of nest site selection of Slender-billed Gulls nesting in two colony sites of the northern Po Delta (NE Italy), in 2020 and 2022

1. táblázat A Pó-delta (ÉK-Olaszország) két kolóniájában fészkelő vékonycsőrű sirályok fészkelőhely-választásának drónfelvételekből származó képalapú értékelése 2020-ban és 2022-ben

Parameter / quadrats	Occupied	Non occupied	All	P
Scanno Bottonera 2020	N = 12	N = 118	N = 130	
Elevation above water level (cm) [a]	39±3	35±8	36±7	0.001
Bare sand (%) [b]	97±3	86±24	87±24	<0.001
Vegetation cover (%) [b]	2±3	1±1	1±1	0.024
Bivalve shells (%) [b]	0±0	0±0	0±0	-
Water (%) [b]	1±3	14±24	13±24	<0.001
– internal water = lagoon (%) [b]	1±3	7±19	7±19	0.023
– external water = sea (%) [b]	0±0	7±18	6±17	<0.001
Distance from the sea (m) [a]	50±6	26±29	28±20	<0.001
Distance from the lagoon (m) [a]	16±7	34±22	32±21	0.001
Distance from tideline (m) [a]	13±7	11±9	11±9	0.295
Wrecked tree trunk/branches (%) [c]	42	39	39	1.000
Peripheral/central location (%) [c]	8/92	32/68	30/70	0.107
Number of other breeding species [a]	0.3±0.6	0.1±0.3	0.2±0.4	<0.001
Association between with other species (%) [d]				
– Oystercatcher *Haematopus ostralegus*	0	2	1	0.649
– Pied Avocet *Recurvirostra avosetta*	0	5	5	0.424
– Kentish Plover *Charadrius alexandrinus*	0	3	2	0.576
– Sandwich Tern *Thalasseus sandvicensis*	33	3	5	<0.001
– Common Tern *Sterna hirundo*	0	4	4	0.467
– Little Tern *Sternula albifrons*	0	6	5	0.424
Dossi Scardovari 2022	N = 3	N = 30	N = 33	*P*
Elevation above water level (cm) [a]	30±0	25±7	26±7	0.002
Bare sand (%) [b]	0±0	0±0	0±0	-
Vegetation cover (%) [b]	0±0	0±0	0±0	-
Bivalve shells (%) [b]	38±24	50±17	39±24	0.345
Water (%) [b]	50±17	62±24	61±26	0.345
– internal water (%) [b]	37±35	30±35	30±34	0.808
– external water (%) [b]	13±23	33±34	31±33	0.308
Wrecked tree trunk/branches (%) [c]	0.3±0.6	0.1±0.3	0.2±0.4	<0.001
Number of other breeding species [a]	0.3±0.6	0.1±0.3	0.3±0.5	0.508
Wrecked tree trunk/branches (%) [c]	67	10	15	0.053
Number of other breeding species [a]	0.3±0.6	0.1±0.3	0.2±0.4	<0.001
Association between with other species (%) [d]				
– Oystercatcher	0	3	3	0.748
– Pied Avocet	0	3	3	0.748
– Sandwich Tern	67	33	3	0.001

Environmental variables were measured at 100-m^2 quadrats occupied or not by Slender-billed Gulls. N= number of 10 × 10 m quadrats. The mean ± SD is shown. [a] *t* test carried out on the variable square root transformed. [b] *t* test carried out on the variable arc-sin square root transformed. [c] Difference tested by means of a χ^2 test on the count data. [d] Association tested by means of Cramer's Phi.

Habitat use showed only a few differences from a random pattern, as can be deduced from the distribution of nests on the barrier islands *(Figures 1, 2, 3, 6)*. We considered for the present analysis both colony sites. The site on the barrier island *(Figures 1, 2, 3)*, which hosted in different locations also the colonies of 2018 and 2021, was analysed only for the 2020 breeding season to avoid bias. In addition, we analysed separately the 2022 site *(Figures 5, 6; Table 1)*. For both colony sites, we investigated associations between species.

In the outer barrier island, used in 2020, quadrats hosting nesting Slender-billed Gull were located farther from the sea and nearer to the lagoon, contained more external water and less internal water, and had more vegetation *(Table 1)*. In addition, occupied quadrats hosted a larger number of nests of other species *(Table 1)*, since Slender-billed Gulls were associated to Sandwich Terns (Cramer's Phi = 0.559; P = 0.001), but not to Little Terns, Common Terns, Avocets, Oystercatchers and Kentish Plovers (P > 0.05 for all the comparisons).

Logistic regression analysis identified four variables as significant predictors of nest location: distance both to the sea and the rear lagoon (B = 0.082±0.024, Wald 11.288, df = 1, P = 0.001 and B = -0.044±0.017, Wald = 6.540, df = 1, P = 0.011, respectively), vegetation cover (B = 0.662±0.166, Wald = 15.995, df = 1, P < 0.001), and presence of Sandwich Terns (B = 2.395±0.847, Wald = 12.163, df = 1, P < 0.000). According to the method of variable reduction, two variables were excluded from further multivariate regression analysis: 1) Sandwich Tern presence, due to their active attraction for other breeding Laridae, which could have altered the outcome of the analysis (see Discussion), and 2) distance to the sea (to reduce collinearity). Only two variables were thus entered in a multivariate logistic model discriminating between quadrats with and without Sandwich Terns to be tested: % vegetation cover and distance to the back lagoon of quadrats. Both parameters (B = 0.716±0.187, Wald = 14.729, df = 1, P < 0.001 and B = -0.058±0.24, Wald = 5.958, df = 1, P = 0.015, respectively) were used in the multivariate stepwise binary logistic regression (correctly reclassified cases = 90.8%).

In the bivalve shell islet colony in 2022, Slender-billed Gulls selected quadrats (N = 3) higher above the water level in comparison to the remaining (N = 30) that hosted a larger number of other nesting species *(Table 1)*. Slender-billed Gulls were associated to Sandwich Terns (Cramer's Phi = 0.559; P = 0.001), but not to Avocets, nor to Oystercatchers. No other significant difference was found in relation to Slender-billed Gull presence. According to the method of variable reduction, Sandwich Tern presence was excluded from multivariate regression analysis (as well as number of other species, which is a function of the former) due to their active attraction for Slender-billed Gulls, which could have altered the outcome of the analysis. Thus, only elevation AWL was entered in logistic regression, but it was not significantly associated to Slender-billed Gull presence (B = 1.825±968.388, Wald = 0.000, df = 1, P = 0.998).

Additionally, disturbance to Slender-Billed Gulls due to drone surveys was negligible, as birds frequently ignored the flying intruder entering the colony. Breeders of other species showed different insensitivity to intruding drones: Sandwich Terns sometimes fled away on drone arrival over the sub-colonies, but they came back to nest in less than one minute. Avocets fled away on drone arrival, whereas Oystercatchers frequently attacked the drone.

Discussion

The main finding of our study is that Slender-billed Gulls are failing in their attempt to colonise the barrier islands of the northern Po Delta. Productivity in the first five years was zero, mostly due to colony sites flooded by high tides and storms. Extreme high tides have become a frequent occurrence in spring during the last decade along the northern Adriatic wetlands (data from Comune di Venezia 2022). This phenomenon, along with human disturbance in particular causing habitat loss due to construction of illegal huts, forced waterbirds which used to nest there (Oystercatchers, Little Terns, Kentish Plovers) to leave barrier islands and move into the nearby fish farms. These are not subjected to tidal excursions since water level is strictly artificially regulated (Scarton *et al*. 2018, Valle & Verza 2022).

Sea level rise dramatically affects coastal sites (Newton *et al.* 2020), thus being the greatest threat to the survival of many seabird species, including gulls and terns (Reynolds *et al*. 2015, Dias *et al*. 2019). Worldwide, it was observed that previously suitable and safe nesting sites have progressively become unstable and unreliable due to frequent flooding by extreme high tides occurring in spring, i.e. during the breeding season (Scarton & Valle 2013, Bonther *et al*. 2014, Koffijberg *et al*. 2016, Tattoni *et al*. 2020, Ritenour *et al*. 2022). Slender-billed Gulls selected open areas of barrier islands in low AWL areas free from dunes and close to the tideline. They are known to locate nests far from the sea and close to the lagoon (possibly to evade high wave during storm with strong winds), actively preferring areas with vegetation (though <5%) rather than bare areas, facing the lagoons staying behind the islands. Slender-billed Gull in the northern Adriatic are expanding in numbers, but their use of apparently suitable nesting sites such as the barrier islands led to a null reproductive output. For this reason, we deem the barrier islands to nowadays act as an ecological trap, i.e. a low-quality (in this case, in terms of reproductive output) habitat that individuals prefer according to once reliable cues, which are inducing instead a maladaptive habitat selection due to environmental changes (Hale & Swearer 2016, Sherley *et al*. 2017, Greggor *et al*. 2019). Barren, low-elevated sites, relatively far from the mainland and close to brackish lagoons are usually the preferred nesting habitats for this species due to the low interspecific competition and absence of mammalian predators (Sanz-Aguilar *et al*. 2014). The observed increase in sea level rise and spring or summer storms are nevertheless leading to more and more frequent loss of clutches, as we observed in our study area. These man-induced phenomena are taking place in a very short period, thus birds have not yet learnt to cope with them. Although our study does not formally respect the three criteria proposed by Robertson and Hutto (2006) to define an “ecological trap”, a mortality rate of 100% in each of four years may qualify as such. An intriguing question is why, after years of complete reproductive unsuccess, the gulls kept on nesting at the same colony sites. The Slender-billed Gull is typical of unstable and ephemeral habitats and shows population dynamics dominated by dispersion, breeding failures, irregular reproduction and weak interannual breeding site fidelity, with colonies that change sites almost each year (Sanz-Aguilar *et al*. 2014, Francesiaz *et al*. 2017). The Po Delta, as the French and Spanish sites, lye at the extreme western edge of the areal distribution of the species; it has been observed that many birds come from the large Black Sea populations, whereas a north African origin has been suggested for the Spanish colonies (Sanz-Aguilar *et al*. 2014, De Faveri 2022). It may thus be possible that different group of birds, in a species where group tenacity is high (Francesiaz *et al*. 2017), try each year to occupy an apparently suitable nesting site, only to move away the following year; nevertheless, we do not have ring readings to corroborate this hypothesis so far.

Another factor playing a key role in failure of colonisation of the Po Delta by Slender-billed Gulls is progressive habitat loss. The unauthorised construction of huts in the barrier islands of the Po Delta by sun-bathers and hunters has been dramatically increasing during the last 30 years: in the late nineties of the past century, only a few huts were found along the entire coastline of the Po Delta (pers. obs.), whereas up to 11 huts in a 0.5 km stretch of barrier island (from 44°52’34.80”N – 12°29’02.90”E to 44°52’20.83”N – 12°28’53.67”E) could be seen on Google Earth in the last years (https://www.google.com – imagery of September 2018). Such a high density of artefacts and related human presence by sun-bathers virtually excludes waterbirds from breeding, forcing them to alternative habitats when available.

This scenario has been made even worse by the increase in number of Red Foxes in the Po Delta over the last decade, in line with a population increase and range expansion observed for the whole of northern Italy (Bon 2017). In recent years, many observations of Red Foxes were reported not only on barrier islands connected with the mainland (where they were infrequently observed also in the past; Verza 2003), but also in outer barrier islands. In these islands, not accessible from the mainland, some reproductive periods of Red Foxes have recently been recorded (Verza & Cattozzo 2015).

Slender-billed Gulls colonising the Po Delta showed some flexibility in nest habitat adoption, settling both on outer barrier islands and on tiny bivalve shell islets in an inner lagoon. Though this flexibility was not enough to avoid breeding failure over a five-year period from colonisation, it gives a glimpse on the possible adoption of further habitat types. Dredge islands, built in the northern Po Delta over the last thirty years and those that will be built in the next years, may probably be suitable colony sites. Dredge islands or similar artificial sites are also commonly accepted and used for nesting by gulls and terns (Van Zomeren *et al*. 2019, Ritenour *et al*. 2022); sometimes, the building of artificial islands has been used as a way to compensate for the loss of previously used natural sites (Stienen *et al*. 2005, Gamblin *et al.* 2022). In southern France, the use of artificial colony sites led to an increase of 14% of Slender-billed Gulls in 2011−2017 (Schwartz *et al*. 2022), while in the lagoon of Venice, several waterbirds regularly use dredge islands to nest (Scarton & Valle 2015, Scarton 2017).

The settlement of an initial breeding colony on an artificial mound in a fish farm in 2022, despite being only a few pairs accompanied by nesting failure, is a good indicator for the species. Other larids, such as Mediterranean Gulls *Ichthyaetus melanocephalus* and Gull-billed Terns *Gelochelidon nilotica,* recently colonised the fish farms of the Po Delta, with increasing populations (Scarton *et al*. 2018, Valle & Verza 2022) and good productivity (Grussu *et al*. 2019 and *pers. obs*.). If Slender-billed Gulls will switch to nest in nearby fish farms, these could provide plenty of suitable breeding sites safe from tidal flooding and with very low predation pressure, allowing sufficient productivity. At the moment, after five years from settlement, Slender-billed Gulls are failing to colonise the barrier islands of the Po Delta.

Acknowledgements

We would like to thank Giuliano Zanellato for his help in the field. We appreciate the time and effort of the Editor and the Referee and we believe that addressing and accepting all their suggested revisions has enhanced the quality of our manuscript. The drone flights complied with the laws in force at the time of the study, which did not require a license for drones of a weight less than 2 kg. This study was financed by the authors.

References

BirdLife International 2021. European Red List of Birds. – Office for Official Publications of the European Communities, Luxembourg

BirdLife International 2022. Species factsheet: *Larus genei*. – http://www.birdlife.orgon 02/07/2022.

Bon, M. 2017. Nuovo Atlante dei Mammiferi del Veneto [New Atlas of Mammals of the Veneto Region]. − WBA Monographs 4, Verona, Italy (in Italian)

Bonther, D. N., MacLean, S. A., Shah, S. S. & Moglia, M. C. 2014. Storm-induced shifts in optimal nesting sites: a potential effect of climate change. − Journal of Ornithology 155: 631–638. DOI: 10.1007/s10336-014-1045-9

Brichetti, P. & Fracasso, G. 2018. The Birds of Italy. Vol. 1. Anatidae-Alcidae. – Edizioni Belvedere, Latina, Italy

Comune di Venezia 2022. https://www.comune.venezia.it/it/content/archivio-storico-livello-marea-venezia

Day, J. W., Ibáñez, C., Pont, D. & Scarton, F. 2019. Status and sustainability of Mediterranean Deltas: The case of the Ebro, Rhône, and Po Deltas and Venice Lagoon. – In: Wolanski, E., Day, J. W., Elliott, M. & Ramachandran, R. (eds.) Coasts and Estuaries. – Elsevier, New York, USA.

De Faveri, A. 2022. Gabbiano roseo *Larus genei*. – In: Lardelli, R., Bogliani, G., Brichetti, P., Caprio, E., Celada, C., Conca, G., Fraticelli, F., Gustin, M., Janni, O., Pedrini, P., Puglisi, L., Rubolini, D., Ruggieri, L., Spina, F., Tinarelli, R., Calvi, G. & Brambilla. M. (eds.) Italian breeding birds atlas (in Italian). – Edizioni Belvedere

Dias, M. P., Martin, R., Pearmain, E. J., Burfield, I. J., Small, C., Phillips, R. A., Yates, O., Lascelles, B., Borboroglu, P. B., & Croxall, J. P. (2019). Threats to seabirds: a global assessment. Biological Conservation, 237, 525–537.

Ersts, P. J. 2019. DotDotGoose v. 1.4.0. – American Museum of Natural History, Center for Biodiversity and Conservation. – https://biodiversityinformatics.amnh.org/open_source/dotdotgoose

Ferrarin, C., Lionello, P., Orlić, M., Raicich, F. & Salvadori, G. 2022. Venice as a paradigm of coastal flooding under multiple compound drivers. – Scientific Reports 12: 1–11. DOI: 10.1038/s41598-022-09652-5

Francesiaz, C., Farine, D., Laforge, C., Béchet, A., Sadoul, N. & Besnard, A. (2017). Familiarity drives social philopatry in an obligate colonial breeder with weak interannual breeding-site fidelity. – Animal Behaviour 124: 125–133. DOI: 10.1016/j.anbehav.2016.12.011

Gamblin, A. E., Darrah, A. J., Woodrey, M. S. & Iglay, R. B. 2022. Coastal bird community response to dredge spoil tidal marsh restoration at New Round Island, Mississippi, USA. – Restoration Ecology e13775. DOI: 10.1111/rec.13775

Greggor, A. L., Trimmer, P. C., Barrett, B. J. & Sih, A. 2019. Challenges of learning to escape evolutionary traps. – Frontiers in Ecology and Evolution 7: 408. DOI: 10.3389/fevo.2019.00408

Grussu, M., Scarton, F., Verza, E. & Valle, R. G. 2019. Long-term trends and breeding parameters of Gull-billed Tern *Gelochelidon nilotica* in three Italian coastal sites. – Rivista Italiana di Ornitologia – Research in Ornithology 89: 3–12. DOI: 10.4081/rio.2019.438

Hale, R. & Swearer, S. E. 2016. Ecological traps: current evidence and future directions. – Proceeding of the Royal Society B 283: 20152647. DOI: 10.1098/rspb.2015.2647

Hodgson, J. C. & Koh, L. P. 2016. Best practice for minimising unmanned aerial vehicle disturbance to wildlife in biological field research. – Current Biology 26(10): 404–405. DOI: 10.1016/j.cub.2016.04.001

Keller, V., Herrando, S., Vorísek, P., Rodríguez-Franch, M., Kipson, M., Milanesi, P., Marti, D., Anton, M., Klvanova, A., Kalyakin, M. V., Bauer, H. G. & Foppen, R. P. B. 2020. European Breeding Bird Atlas 2. – Lynx Edicions, Barcelona, Spain

Koffijberg, K., Frikke, J., Hälterlein, B., Reichert, G. & Andretzke, H. 2016. Breeding birds in trouble: a framework for an action plan in the Wadden Sea. – CWSS, Wilhelmshaven

Krebs, C. J. 1978. Ecology: The Experimental Analysis of Distribution and Abundance. – Harper, New York, USA

Medvedev, I. P., Vilibić, I. & Rabinovich, A. B. 2020. Tidal resonance in the Adriatic Sea: Observational evidence. – Journal of Geophysical Research: Oceans 125: e2020JC016168. DOI: 10.1029/2020JC016168

Newton, A., Icely, J., Cristina, S., Perillo, G. M. E., Turner, R. E., Ashan, D., Cragg, S., Luo, Y., Tu, C., Li, Y., Zhang, H., Ramesh, R., Forbes, D. L., Solidoro, C., Béjaoui, B., Gao, S., Pastres, R., Kelsey, H., Taillie, D., Nhan, N., Brito, A. C., de Lima, R. & Kuenzer, C. 2020. Anthropogenic, Direct Pressures on Coastal Wetlands. – Frontiers in Ecology and Evolution 8: 144. DOI: 10.3389/fevo.2020.00144

Reynolds, M. H., Courtot, K. N., Berkowitz, P., Storlazzi, C. D., Moore, J. & Flint, E. 2015. Will the effects of sea-level rise create ecological traps for pacific island seabirds? – PLoS ONE 10: e0136773. DOI: 10.1371/journal.pone.0136773

Ritenour, K., King, S. L., Collins, S. & Kaller, M. D. 2022. Factors affecting nest success of colonial nesting waterbirds in southwest Louisiana. – Estuaries and Coasts 45: 897–912. DOI: 10.1007/s12237-021-00993-4

Robertson, B. A. & Hutto, R. L. 2006. A framework for understanding ecological traps and an evaluation of existing evidence. – Ecology 87(5): 1075–1085.

Sanz-Aguilar, A., Tavecchia, G., Afán, I., Ramírez, F., Doxa, A., Bertolero, A., Gutíerrez-Expósito, C., Forero, M. G. & Oro, D. 2014. Living on the edge: demography of the Slender-billed Gull in the Western Mediterranean. – PLoS ONE 9(3): e92674.

Scarton, F. 2017. Long-term trend of the waterbird community breeding in a heavily man-modified coastal lagoon: the case of the Important Bird Area "Lagoon of Venice". – Journal of Coastal Conservation 21: 35−45. DOI: 10.1007/s11852-016-0470-8

Scarton, F., Boschetti, E., Guzzon, C., Kravos, K., Panzarin, L., Utmar, P., Valle, R. G. & Verza, E. 2005. Caradriformi, Charadriiformes e Volpoca, *Tadorna tadorna*, nidificanti sulle coste del Nord Adriatico (Friuli – Venezia Giulia e Veneto) nel triennio 2000–2002. – Rivista Italiana di Ornitologia – Research in Ornithology 75: 37–54 (in Italian)

Scarton, F. & Valle, R. G. 2020. Drone assessment of habitat selection and breeding success of Gull-billed Tern *Gelochelidon nilotica* nesting on low-accessibility sites: a case study. – Rivista Italiana di Ornitologia – Research in Ornithology 90: 69–76. DOI: 10.4081/rio.2020.475

Scarton, F., Verza, E., Guzzon, C., Utmar, P., Sgorlon, G. & Valle, R. G. 2018. Laro-limicoli (Charadriiformes) nidificanti nel litorale nord adriatico (Veneto e Friuli-Venezia Giulia) nel periodo 2008−2014: consistenza, trend e problematiche di conservazione [Waders, gulls and terns (Charadriiformes) nesting in the North Adriatic coast (Veneto and Friuli-Venezia Giulia) in the period 2008–2014: numbers, trends and conservation issues]. – Rivista Italiana di Ornitologia – Research in Ornithology 88: 33–41. DOI: 10.4081/rio.2018.418 (in Italian)

Scarton, F. & Valle, R. 2015. Long-term trends (1989–2013) in the seabird community breeding in the lagoon of Venice (Italy). – Rivista Italiana di Ornitologia – Research in Ornithology 85(2): 19–28. DOI: 10.4081/rio.2015.232

Sherley, R. B., Ludynia, K., Dyer, B. M., Lamont, T., Makhado, A. B., Roux, J. P., Scales, K. L., Underhill, L. G. & Votier, S. C. 2017. Metapopulation tracking juvenile penguins reveals an ecosystem-wide ecological trap. – Current Biology 27(4): 563–568.

Schwartz, T., Besnard, A., Pin, C., Scher, O., Blanchon, T., Béchet, A. & Sadoul, N. 2022. Efficacy of created and restored nesting sites for the conservation of colonial Laridae in the south of France. – Conservation Biology e14005. DOI: 10.1111/cobi.14005

Šepić, J., Pasarić, M., Međugorac, I., Vilibić, I., Karlović, M. & Mlinar, M. 2022. Climatology and process-oriented analysis of the Adriatic Sea level extremes. – Progress in Oceanography 209: 102908. DOI: 10.1016/j.pocean.2022.102908

Sokal, R. R. & Rohlf, F. J. 1981. Biometry. – W. H. Freeman, New York, USA.

Stienen, E. W., Courtens, W., Van De Walle, M., Van Waeyenberge, J. & Kuijken, E. 2005. Harbouring nature: port development and dynamic birds provide clues for conservation. – Proceedings 'Dunes and Estuaries': 381–392. https://www.vliz.be/en/imis?module=ref&refid=76346

Tattoni, D. J., Mordecai, E. A. & Stantial, M. L. 2020. Spatial and temporal changes in nesting behavior by Black Skimmers *(Rynchops niger)* in New Jersey (USA) from 1976–2019. – Waterbirds 43: 307–313. DOI: 10.1675/063.043.0309

Valle, R. G., Scarton, F. & Verza, E. 2022. Recent settlement of two new breeding species in the northern Po Delta (Veneto – Italy): the Slender-billed Gull *(Larus genei)* and the Sandwich Tern *(Thalasseus sandvicensis)*. – Lavori – Società Veneziana di Scienze Naturali 47: 117–120.

Valle, R. G. & Scarton, F. 1999. Habitat selection and nesting association in four species of *Charadriiformes* in the Po Delta (Italy). – Ardeola 46(1): 1–12. https://www.ardeola.org/uploads/articles/docs/392.pdf

Valle, R. G. & Scarton, F. 2018. Uso dei droni nel censimento degli uccelli acquatici nidificanti nel Nord Adriatico [Use of drones in the census of breeding waterbirds in the North Adriatic Sea]. – Bollettino del Museo di Storia Naturale di Venezia 69: 69–75 (in Italian) https://drive.google.com/file/d/1lH4AI24dD85AlCq4C43GAEMWWqMaj6KU/view

Valle, R. G. & Verza, E. 2020. I laro-limicoli (Charadriiformes) nidificanti nel Delta del Po Veneto (RO) nel periodo 2015–2018. [Waders, gulls and terns (Charadriiformes) nesting in the Veneto Po Delta (RO) in the period 2015–2018]. – Bollettino del Museo di Storia Naturale di Venezia 71: 123–126. (in Italian) https://drive.google.com/file/d/1ajCdSJrZCPeOJ4bBTEJg3KRUGCdfSwEA/view (in Italian)

Valle, R. G. & Scarton, F. 2021a Drone-conducted counts as a tool for the rapid assessment of productivity of Sandwich Terns *(Thalasseus sandvicensis)*. – Journal of Ornithology 162(2): 621–628. DOI: 10.1007/s10336-020-01854-w

Valle, R. G. & Scarton, F. 2021b Monitoring the hatching success of gulls Laridae and terns Sternidae: a comparison of ground and drone methods. – Acta Ornithologica 56: 241–254. DOI: 10.3161/00016454AO2021.56.2.010

Van Zomeren, C. M., Acevedo-Mackey, D., Murray, E. O. & Estes, T. J. 2019. Maintaining salt marshes in the face of sea level rise – Review of literature and techniques. – US Army Corps of Engineers, ERDC/EL SR-19-4. https://erdc-library.erdc.dren.mil/jspui/handle/11681/33297

Verza, E. 2003. Contributo alla conoscenza della Teriofauna della provincia di Rovigo. Atti IV Convegno Faunisti Veneti [Contribution to the knowledge of the mammals of the province of Rovigo]. – Proceedings IV. Conference of the Associazione Faunisti Veneti – Natura Vicentina 7: 14–20 (in Italian)

Verza, E. & Cattozzo, L. 2015. Atlante lagunare costiero del Delta del Po [Po Delta Coastal Lagoon Atlas]. – Consorzio di Bonifica Delta del Po, Regione del Veneto – Associazione Culturale Naturalistica Sagittaria. Rovigo, Italy (in Italian)

Wetlands International 2022. Waterbird Population Estimates. – https://wpe.wetlands.org (accessed: 24/12/2022)

Ornis Hungarica 2023. 31(1): 88–110.
DOI: 10.2478/orhu-2023-0006

Relationship between landscape structure and the diet of Common Barn-owl *(Tyto alba)* at different distances from the Drava River ecological corridor

Győző F. Horváth*, Kinga Mánfai & Adrienn Horváth

Received: May 02, 2023 – Revised: May 16, 2023 – Accepted May 17, 2023

Horváth, Gy. F., Mánfai, K. & Horváth, A. 2023. Relationship between landscape structure and the diet of Common Barn-owl *(Tyto alba)* at different distances from the Drava River ecological corridor. – Ornis Hungarica 2023(1): 88–110. DOI: 10.2478/orhu-2023-0006

Abstract This study investigated the relationship between landscape structure at different distances from the Drava River in South Hungary and the food composition of the Common Barn-owl. Pellets were collected from 15 villages between 2006 and 2008. Based on the CORINE land cover elements, five land use types were determined, and five landscape metrics were calculated to compare land use and landscape structure in the three distance zones. There were significant differences in the Shannon and Simpson diversity of small mammal assemblages between the three areas. A positive relationship was detected between the distance categories and the abundance distribution of the Striped Field Mouse and Field Vole. The relative abundance of the Striped Field Mouse in the diet of Common Barn-owl was influenced by the increase in the mean perimeter/area ratio and the mean of the contiguity index. The value of the trophic level index was negatively influenced by the decrease in crop patches and the increase in pasture and grassland areas, which land use types facilitate the distribution of insectivores. Our results suggest that landscape characteristics influence prey occurrence in hunting areas and the frequency-dependent availability of small mammal prey, which determines the resource utilization of Common Barn-owl.

Keywords: diet composition*, Tyto alba,* pellet analysis, CORINE land cover, landscape structure

Összefoglalás Jelen tanulmányban a Dráva folyótól különböző távolságokban jellemző tájszerkezet és a gyöngybagoly táplálék-összetétele közötti összefüggést vizsgáltuk köpetelemzés alapján. A felhasznált mintákat 15 faluból gyűjtöttük 2006 és 2008 között. Az elemzéshez a CORINE felszínborítás alapján 5 tájhasználati típust határoztunk meg, illetve 5 tájindexet számítottunk. Mind a Shannon, mind a Simpson diverzitási mutató szignifikánsan különbözött a három távolság összehasonlításában. Pozitív összefüggést mutattunk ki a három távolságkategória és a pirók erdeiegér, valamint a csalitjáró pocok abundanciája között. Emellett a pirók erdeiegér gyakoriságát a kerület/terület arány és a szomszédsági index értékének növekedése is befolyásolta. A trofikus index (TLI) értékére negatív hatással volt az agrárterületek arányának emelkedése, és pozitívan befolyásolta a legelők és gyepek mennyiségének növekedése, amely utóbbi területhasználati módok elősegítik a rovarevők elterjedését. Eredményeink arra utalnak, hogy a táj jellemzői befolyásolják a zsákmány előfordulását és gyakoriságtól függő elérhetőségét a baglyok vadászterületén, ami meghatározza a gyöngybaglyok forráshasznosítását.

Kulcsszavak: táplálék-összetétel*, Tyto alba,* bagolyköpet elemzés, CORINE felszínborítás, tájszerkezet

University of Pécs, Faculty of Science, Institute of Biology, Department of Ecology 7624 Pécs, Ifjúság utca 6., Hungary
**corresponding author, e-mail: hgypte@gamma.ttk.pte.hu*

Introduction

Human-induced land use and intensive agricultural practice with the extensive use of fertilizers and pesticides have a significant impact on biodiversity (Sala *et al.* 2000, Stoate *et al.* 2001, 2009, Zebisch *et al.* 2004, Geiger *et al.* 2010). The rich diversity of agricultural landscapes greatly depends on the types of land use, sizes and shapes of fields, as well as the abundance and pattern of semi-natural elements of the landscape (Billeter *et al.* 2008). However, the change in agricultural practices and intensification led to the reduction of heterogeneity and quality of landscape composition and structure as available habitat for wildlife, especially for the environmentally sensitive Common Barn-owl *(Tyto alba)* (Colvin 1985, Gorman & Reynolds 1993, Burel *et al.* 2004, Martin *et al.* 2010, Hindmarch *et al.* 2012). This opportunistic owl species occurs in most of these human-modified and disturbed open landscapes (grasslands, farmlands, agriculture fields, fallow, crop margins and hedgerows, woodland edges, river banks) (Andries *et al.* 1994, Salvati *et al.* 2002, Meek *et al.* 2003, Martínez & Zuberogoitia 2004, Frey *et al.* 2011), and as a top predator, it has an important role in the trophic cascades of agricultural ecosystems, especially in rodent control (Meyrom *et al.* 2009, Paz *et al.* 2013). Diet analysis of Common Barn-owl is widely used all over the world because it is a cosmopolitan nocturnal raptor, which prefers mainly small mammals (Jaksić *et al.* 1982, Mikkola 1983, Taylor 2004). This method, as an indirect approach, has been extensively used to investigate the distribution and evaluate the population and community response of small mammals at various temporal and spatial scales in a given region (e.g. Meek *et al.* 2012, Torre *et al.* 2015a), or along geographical and vegetative gradients (e.g. Leveau *et al.* 2006, Trejo & Lambertucci 2007, Torre *et al.* 2015b), as well as, along rural-urban gradients (Teta *et al.* 2012, Hindmarch & Elliott 2015, Iannella *et al.* 2016). In addition, numerous studies used diet analysis of Common Barn-owl as a suitable tool to investigate the composition of small mammal assemblages and species or guild frequency depending on the change in agricultural activity (Love *et al.* 2000, Bose & Guidali 2001, Millán de La Peña *et al.* 2003, Askew *et al.* 2007, Charter *et al.* 2009, Lyman 2012). Based on landscape analysis, the results of several studies suggested that the diet of Common Barn-owl, particularly small mammal composition and diversity, was affected by agricultural activity (Millán de La Peña *et al.* 2003, Askew *et al.* 2007, Marti 2010), landscape heterogeneity (Torre *et al.* 2015a) as well as land use and landscape composition (Burel *et al.* 2004, Milchev 2015, Veselovský *et al.* 2017, Horváth *et al.* 2018, Horváth *et al.* 2022).

The Common Barn-owl is a widely distributed owl species in Hungary, particularly along the lowland farmland areas. Analyses of the food habits of Common Barn-owl, focusing on the composition of small mammals, were intensive in the last three decades in the southern part of Transdanubia, which included the region of Drava River (Horváth 1998, 2000, Purger 1998). Although most of these studies were baseline surveys and did not investigate the dependence of food composition on the type of land use, the difference in small mammal communities was investigated by pellet analysis in a previous study that compared the three Drava River sections using landscape features (Horváth *et al.* 2005).

The aims of the present study are: 1) to compare the food habits of Common Barn-owl, especially the small mammal assemblages at the three different distances from the Drava

River ecological corridor, 2) to compare the estimates of species richness and diversity of small mammal prey assemblages along this environment gradient, and 3) to analyse the effects of landscape structure on the distribution of relative frequencies of different small mammal taxa.

Material and Methods

Study area

The study was conducted in the south-eastern part of the Transdanubian region in South Hungary, where sampling sites were situated in Baranya county (4429.6 km²) (32° 30′ N, 35° 30′ E) in two mesoregions (Drava Floodplain, Mecsek and Tolna-Baranya hill country) at three different distances (see below) from the Drava River ecological corridor. The climate of these regions is determined by a Mediterranean effect, with a high number of sunny hours, relatively low temperature fluctuations, and mild winters. The area of the Drava Floodplain includes the flood-basin of the Drava River; altitude varies between 89 and 212 metres, its area is 1,300 km^2. The Drava River represents the southern border of both the mesoregion and the country. The climate of this mesoregion is moderately warm and humid. The annual amount of precipitation increases from east to west: 630–680 mm in the east, while more than 720 mm in the west. The Mecsek and Tolna-Baranya hill country is situated in the north of the previous mesoregion and its area is 4,400 km^2, where the yearly mean precipitation is 680–720 mm.

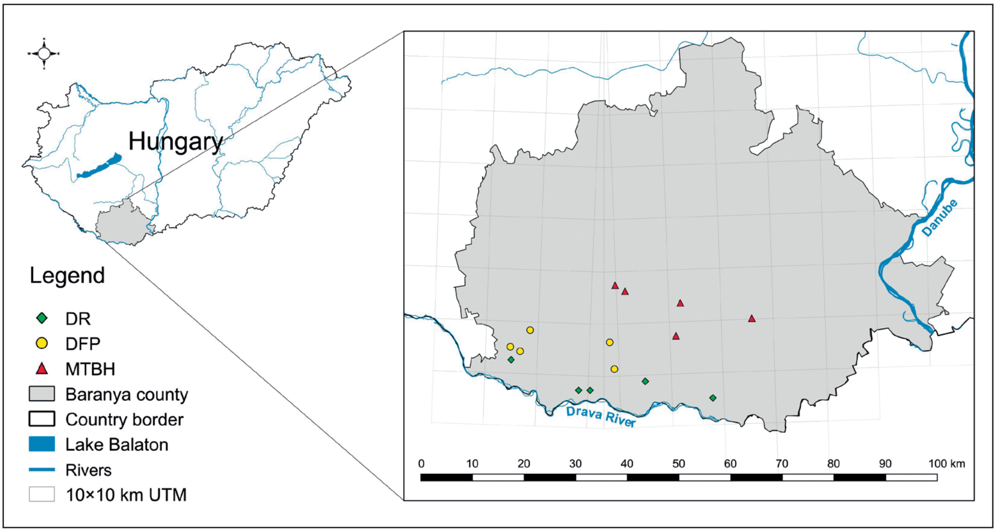


Figure 1. Study area in the South Transdanubia region, Hungary, showing the location of sampled nesting sites (settlements) in the distance categories to the north of the Drava River (DR: Drava River, DFP: Drava Floodplain, MTBH: Mecsek and Tolna-Baranya hill country)

1. ábra A mintavételi terület Dél-Dunántúlon, Magyarországon, feltüntetve a vizsgált költőpárok fészkelőhelyeit a Drávától északra fekvő különböző távolságkategóriákban (DR: Dráva, DFP: Drávamenti-síkság, MTBH: Mecsek és Tolna-Baranyai dombvidék)

Pellets and prey remains were collected from 15 villages (nest boxes were placed in 11 villages, while 'natural' environment of church towers were sampled in 4 villages) at the end of the Common Barn-owl breeding season between 2006 and 2008. Settlements belonged in three distance categories to the north of Drava River: near Drava River (DR: 3.56 ± 1.24 km SE, n = 5), in Drava Floodplain (DFP: 9.17 ± 2.6 km SE, n = 5) and further north in Mecsek and Tolna-Baranya hill country (MTBH: 20.04 km, ± 4.25 km SE, n = 5) *(Figure 1)*. The distance between the three sampling zones differed significantly (one-way ANOVA: $F_{2,\,12}$ = 39.92, P < 0.001; Tukey's HSD test – DR vs DFP: P = 0.028, DR vs MTBH: P < 0.001, DFP vs MTBH: P < 0.001). A total of 121 samples and 2,552 pellets (DR: 105.4 ± 29.11 SE; DFP: 261.2 ± 88.17 SE; MTBH: 143.8 ± 66.74 SE) were analysed from the 15 localities.

Sample collection methodology

Pellets were processed by the dry technique that is, the individual pellets were broken down by hand (Schmidt 1967) and prey items were identified to the lowest taxonomical level. Small mammals and bats were identified based on skeletal parameters (features of skull, mandible and teeth), following published literature (Schmidt 1967, März 1972, Yalden 1977, Niethammer & Krapp 1978, 1982, 1990, Yalden & Morris 1990). Three different *Apodemus* species, the Wood Mouse *(Apodemus sylvaticus)*, the Yellow-necked Wood Mouse *(A. flavicollis)* and the Pygmy Field Mouse *(A. uralensis)* were categorised commonly as Wood Mice (*Apodemus* spp.). In cases when the Striped Field Mouse *(A. agrarius)* could not be separated from the *Sylvaemus* group (*Apodemus* spp.), the individuals were treated as 'unidentified *Apodemus*'. The sibling species of the *Mus* genus were determined by works of Macholán (1996) and Kryštufek and Macholán (1998). In addition, birds were identified by their skulls, bills, feet, pelvises and feathers (Kessler 2015), and frogs (Anura) by their skulls and bones of postcranial skeleton (Schaefer 1932). If major skeletal elements were missing, prey items were identified to genus (small mammals, birds), to order (frogs) and to class (birds) level.

The number of preys was estimated as the minimum number of individuals (MNI), which were determined according to the same anatomical parts of bones for small mammals (Klein & Cruz-Uribe 1984, Torre *et al.* 2015a, Tulis *et al.* 2015) and skulls, mandibles and long bones for birds, as well as skulls, remnants of ilium or frontoparietal bones for frogs. Furthermore, the percent frequency of occurrence (MNI%) was calculated from the total number of prey found in all the pellets at the three different distance zones. The ratio of insectivores to rodents as an environmental (Paspali *et al.* 2013) or trophic level index (TLI) (Prete *et al.* 2012) and the ratio of Microtinae/Murinae (MMR) were also calculated. The first index is a suitable indicator of possible biotope alteration (Mazzotti & Caramori 1998, Paspali *et al.* 2013), while the MMR is a suitable environmental index for the indication of the agronomic value (Prete *et al.* 2012) of intensively cultivated landscapes.

Determining land use and landscape structure

Landscape features were assessed using photointerpretation of aerial photographs based on the CORINE land cover project (Bossard *et al.* 2000, European Environmental Agency

2007). We used a 1 km radius around each nest sites because this results in an area that approximates the home range (3 km^2) of a Common Barn-owl (Shawyer & Shawyer 1995, Taylor 2004, Bond *et al.* 2005, Hindmarch *et al.* 2012, Horváth *et al*. 2018, 2022). GIS analysis was performed in ArcGIS 10.1 (Environmental Systems Research Institute 2012). Based on CORINE land cover elements of the 15 nest sites, five selected land use types were determined to compare land use in the three landscape zones north of Drava River. The land use classification system included: the percentage of forest (all forest habitats), grassland (including meadows, dry and semi-dry grasslands), cropland (including all agricultural crops and arable fields), pasture, wetland (including river banks, streams, artificial lakes, fishponds, marshes) and urban (all built-up surfaces) areas.

To evaluate the landscape structure of sampling sites, FRAGSTATS version 4.2 was used for spatial statistical analysis (McGarigal *et al.* 2012). This analysis was used only at the landscape level and five landscape indices were calculated: area weighted mean shape index (ha) (SHAPE_MN, mean patch shape complexity weighted by patch area), largest patch index (%) (LPI, percentage of total landscape area comprised by the largest patch), perimeter-area ratio (PARA_MN, mean of perimeter-area ratio, which describes the compactness of patches), mean fractal dimension (FRAC_MN) and the mean of the contiguity index (CONTIG_MN; these indices defined the patch shape complexity and patch boundaries connectedness, respectively), patch richness (PR, which measures the number of patch types present), Shannon diversity of landscape (SHDI, which measures the equitability of the number of patch types and the proportional distribution of area among patch types) (McGarigal 2015).

Statistical analysis

All proportion data of prey abundance were arcsin-square root transformed prior to analyses and tested for normal distribution (Shapiro-Wilk test) and for homogeneity of variance (Levene test). According to the results of these tests, normal distribution was found in case of major small mammal taxa (shrews, rodents, mice), the values of TLI and the Common Vole *(Microtus arvalis)*, the main prey of the Common Barn-owl and a major pest rodent species in Central Europe (Jacob *et al.* 2014, Pavluvčík *et al.* 2015), therefore, one-way analysis of variance (ANOVA) with Tukey's HSD multiple comparison was performed to test eventual significant differences among the landscape units (nest sites) classified into the three distance categories north from Drava River. In case of the total abundance of small mammals, mice, birds and frogs, the assumptions of one-way ANOVA were not met after transformation. Therefore, nonparametric Kruskal-Wallis median test with Dunn's procedure for post hoc comparisons was used. The distribution of different land use categories was analysed similarly by one-way ANOVA comparison of the three different landscape zones.

To evaluate the species richness and diversity of small mammal assemblages among the samples located at three different distances, we estimated Hill numbers (q = 0, species richness; q = 1, Shannon diversity (H); q = 2, Simpson diversity (1-D)), which are ecologically relevant metrics for describing and comparing diversity (Jost 2006, Chao *et al.* 2014). This method is based on seamless rarefaction and extrapolation (R/E) sampling curves of the α diversity metrics (Chao *et al.* 2014, Hsieh *et al.* 2016). In each case, 100 replicate bootstrap runs were used to estimate the 95% confidence interval. Based on publication of Colwell and Elsensohn (2014), the rarefaction curves were extrapolated by doubling the number of individuals.

Variables of land use categories and landscape metrics were summarised by means of Principal Component analysis (PCA) on the correlation matrix. This method allows for independent components of maximum explanatory capacity to be obtained, avoiding the problems of collinearity. To meet the assumptions of homogeneity, arcsin-square root transformed values of land-use relative frequency and log-transformed values of landscape metrics were used in PCA analyses.

Stepwise linear regression was implemented to identify and quantify the relationships between the abundance of different small mammal taxa and the landscape structure. For this analysis, an automated stepwise model selection procedure with the "stepAIC" function was used, with forward selection to obtain the best model using the Akaike Information Criterion (AIC) (Venables & Ripley 2002). We separated two model groups based on the use of the land use categories or the landscape metrics. In case of both model groups, the initial (global) linear models included the arcsin-square root transformed abundance of small mammal species and genera as dependent variables, the distance from the Drava River as a categorical variable, and the first two PCA scores of the landscape variables (land use categories or landscape indices) as continuous variables and all combinations of these variables as interaction effects. We used the R^2 measure to assess the error since the R^2 statistic is commonly interpreted to be the proportion of variance explained by the regression. The best candidate model was selected based on the AIC value and the highest significant (F-statistic) coefficient of determination (R^2). The one-way and Kruskal-Wallis ANOVA, PCA and stepwise linear regression analyses were performed in the statistical program R v3.4.0 (R Development Core Team 2019). Rarefaction curves were drawn using the 'iNEXT' package (Hsieh *et al.* 2016) for R. The statistical tests were considered significant at the level $P \leq 0.05$ as standard in all analyses (Sokal & Rohlf 1995).

Results

Based on all samples, 9,720 prey items were identified from the pellets examined during the three years *(Table 1)*. The diet of the Common Barn-owl was mostly based on small mammal prey (99.33% of all the prey consumed), which was similar in all three sampling distance zones north of Drava River (DR: 98.72%, DFP: 99.52%, MTBH: 99.41%; Kruskal-Wallis test: H(2, 15) = 1.620, P = 0.445). Among other prey, the percent frequency of occurrence of birds (H(2, 15) = 1.340, P = 0.512) and frogs (H(2, 15) = 6.898, P = 0.032) were not significantly different between the three landscape categories, although consumption of frogs was higher near Drava River. Rodents rather than insectivores dominated in the diet of Common Barn-owls. Rodents were highly frequent in the food composition (79.76% of all the preys consumed) and their relative proportion showed an increasing trend from

Table 1. Diet composition of the Common Barn-owl in the three distance categories to the north of Drava River (MNI: minimum number of individuals, MNI%: percentage frequency of occurrence)

1. táblázat A gyöngybagoly táplálék-összetétele a Drávától mért három különböző távolságkategóriában (MNI: minimum ismert egyedszám, MNI%: az előfordulási frekvencia százalékos értéke)

Prey taxon	**Drava River (DR)**		**Drava Floodplain (DFP)**		**Mecsek and Tolna-Baranya hill country (MTBH)**	
	MNI	**MNI%**	**MNI**	**MNI%**	**MNI**	**MNI%**
Mammals						
Sorex araneus	150	7.67	284	5.63	51	1.88
Sorex minutus	51	2.61	74	1.47	15	0.55
Neomys anomalus	45	2.30	34	0.67	31	1.14
Neomys fodiens	8	0.41	24	0.48	5	0.18
Neomys sp.	4	0.20	23	0.46	3	0.11
Crocidura leucodon	96	4.91	143	2.83	81	2.98
Crocidura suaveolens	171	8.74	494	9.79	115	4.23
Myodes glareolus	17	0.87	43	0.85	8	0.29
Microtus agrestis	14	0.72	146	2.89	19	0.70
Microtus arvalis	754	38.55	2076	41.13	1358	50.00
Microtus subterraneus	9	0.46	14	0.28	11	0.41
Arvicola amphibius	26	1.33	77	1.53	6	0.22
Rattus norvegicus	16	0.82	16	0.32	14	0.52
Rattus rattus	0	0.00	2	0.04	0	0.00
Rattus sp.	0	0.00	2	0.04	1	0.04
Apodemus agrarius	199	10.17	347	6.87	161	5.93
Apodemus spp.	184	9.41	578	11.45	441	16.24
Unidentified *Apodemus*	49	2.51	208	4.12	159	5.85
Micromys minutus	44	2.25	95	1.88	24	0.88
Mus spicilegus	40	2.04	106	2.10	71	2.61
Mus musculus	17	0.87	46	0.91	26	0.96
Mus sp.	30	1.53	156	3.09	85	3.13
Muscardinus avellanarius	7	0.36	36	0.71	14	0.52
Glis glis	0	0.00	0	0.00	1	0.04
Eptesicus serotinus	0	0.00	1	0.02	0	0.00
Totals	1931	98.72	5025	99.54	2700	99.41
Birds						
Passer domesticus	5	0.26	5	0.10	4	0.15
Passer montanus	6	0.31	1	0.02	3	0.11
Passer sp.	5	0.26	2	0.04	1	0.04
Hirundo sp.	0	0.00	0	0.00	1	0.04

Prey taxon	**Drava River (DR)**		**Drava Floodplain (DFP)**		**Mecsek and Tolna-Baranya hill country (MTBH)**	
	MNI	**MNI%**	**MNI**	**MNI%**	**MNI**	**MNI%**
Erithacus rubecula	0	0.00	1	0.02	0	0.00
Unidentified Aves	1	0.05	13	0.26	6	0.22
Totals	17	0.87	22	0.44	15	0.55
Frogs						
Pelobates fuscus	6	0.31	1	0.02	1	0.04
Unidentified Anura	2	0.10	0	0.00	0	0.00
Totals	8	0.41	1	0.02	1	0.04
Total MNI	1956		5048		2716	

Drava River to Mecsek and Tolna-Baranya hill country (DR: 71.88%, DFP: 78.21%, MTBH: 88.33%). The transformed percentage by number of rodents differed significantly between landscape zones (one-way ANOVA: $F_{2,12} = 4.892$, $P = 0.028$) and the percent values were significantly higher in the Mecsek and Tolna-Baranya hill country than in the area near the Drava River (post hoc Tukey's HSD test: $P = 0.033$). The percentage of shrews (Soricidae) (all samples: 19.57%) changed conversely along the investigated landscapes (DR: 26.84%, DFP: 21.32%, MTBH: 11.08%) and transformed data differed significantly in comparison of various distances ($F_{2,12} = 4.892$, $P = 0.028$). The abundance of shrews was significantly higher in the ecological corridor near the Drava River than the area of Mecsek and Tolna-Baranya hill country (Tukey's HSD test: $P = 0.033$). According to these results, the ratio of insectivores to rodents was significantly different between the studied areas ($F_{2,12} = 3.887$, $P = 0.049$). The environmental index (TLI) oscillated in a larger range of values in the area near the Drava River (DR: min = 0.11, max = 0.57) than in the other two distance zones (DFP: min = 0.11, max = 0.38; MTBH: min = 0.07, max = 0.17) and showed a decreasing trend depending on the measured distance from the river. Within the group of rodents, mice (Murinae) (DR: 29.60%, DFP: 30.82%, MTBH: 36.16%) and *Microtus*

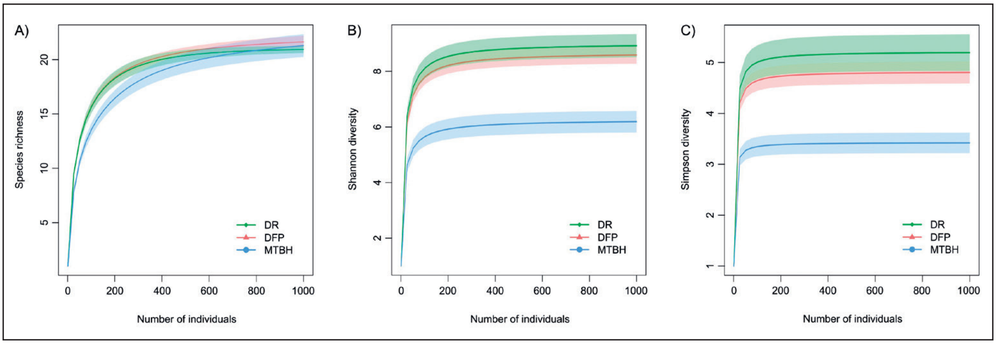


Figure 2. Rarefaction curves illustrating the species richness (A), Shannon diversity (B) and Simpson diversity (C) of the small mammal assemblages of the three different distance categories

2. ábra A három különböző távolságkategóriába tartozó kisemlős együttesek fajgazdagságát (A), Shannon diverzitást (B) és Simpson diverzitást (C) szemléltető ritkasági görbék *arvalis* (DR: 39.05%, DFP: 41.32%, MTBH: 50.30%) occurred in a higher proportion in the diet composition of Common Barn-owls, but these values did not differ between landscape zones (mice: Kruskal-Wallis test: H(2, 15) = 1.040, P = 0.595; *M. arvalis*: one-way ANOVA: $F_{2,12}$ = 3.042, P = 0.085).

Rarefaction analysis demonstrated that the species richness did not differ significantly between the three different distances because the 95% confidence bands of the rarefaction curves overlapped *(Figure 2)*. In the case of Shannon (H) and Simpson (1-D) diversity, due to non-overlapping 95% confidence intervals, these alpha diversity metrics were significantly lower in Mecsek and Tolna-Baranya hill country than the other two landscape distance zones *(Figure 2)*. The rarefaction curves' confidence band of the Drava River and the Drava Floodplain overlap, so the diversity of the small mammal communities of these two areas did not differ significantly *(Figure 2)*.

The first two axes of the PCA performed on land use variables accounted for 70.87% of the common variance (PC1: eigenvalue = 2.823, PC2: eigenvalue = 1.429) *(Table 2)*. The first component (47.10% of the variance) was related positively to the area of forest, grass and pasture while negatively to the area of croplands. The second component (23.80%) was negatively correlated with the forest, wetland and urban patches *(Table 2)*. In case of the PCA performed on landscape indices, the first two axes accounted for 78.70% of the common variance (PC1: eigenvalue = 3.503, PC2: eigenvalue = 2.004). The first component (50.05% of the variance) was negatively associated with the index of CONTIG_MN and Shannon diversity of landscape (SHDI), while positively correlated with PARA_MN *(Table 2)*. The second component (28.63%) was positively related to the indices SHAPE_MN and FRAC_MN and to patch richness (PR) *(Table 2)*.

Considering the relationship between land use categories and small mammal species' abundance, significant final models were detected in the cases of two species; these models included only the distance from Drava River (DR) as a categorical predictor *(Table 3)*. Based on the results of the analysis, a positive association was detected between the distance categories and the abundance distribution of the Striped Field Mouse; the area near the

Table 2. Results of the Principal Component Analyses carried out to synthesis the variation in land use and landscape metrics (bold indicates the absolute values > 0.4)

2. táblázat A vizsgált változók főkomponens értékei a tájhasználat és a tájindexek vonatkozásában (a 0,4 abszolút értéknél nagyobb értékek félkövéren szerepelnek a táblázatban)

	Land use			**Landscape metrics**	
Variable	**PC 1**	**PC 2**	**Variable**	**PC 1**	**PC 2**
Forest	**0.469**	-0.280	LPI	0.380	-0.147
Grass	**0.457**	0.165	SHAPE_MN	0.253	**0.574**
Crop	-0.499	0.403	FRAC_MN	0.313	**0.547**
Pasture	**0.514**	0.132	PARA_MN	**0.484**	-0.094
Wetland	-0.220	**-0.585**	CONTIG_MN	**-0.468**	-0.030
Urban	-0.099	**-0.610**	PR	-0.243	**0.535**
			SHDI	-0.426	0.232

Table 3. Final models of linear regression analysis at species level (significant models are in bold)
3. táblázat A lineáris regresszió végső modelljei a fajok szintjén (a szignifikáns modellek félkövéren szerepelnek a táblázatban)

Small mammal species / Final model	**Model parameters**			
	AIC	**R²**	**F**	**P**
Land use				
M. arvalis ~ Distance	-71.87	0.34	3.04	0.085
***A. agrarius* ~ Distance**	-89.11	0.48	5.63	0.019
Apodemus spp. ~ PC1×Distance + Distance×PC2	-72.06	0.69	1.66	0.276
S. araneus ~ PC1×Distance + PC2×Distance	-71.38	0.71	1.83	0.240
C. suaveolens ~ PC1×Distance + PC2×Distance	-71.55	0.67	1.50	0.320
C. leucodon ~ PC2	-79.93	0.21	3.38	0.089
***M. agrestis* ~ Distance**	-87.20	0.48	5.46	0.021
Landscape metrics				
M. arvalis ~ Distance	-71.87	0.34	3.04	0.085
***A. agrarius* ~ PC1 + Distance + PC2 + PC1×Distance**	-93.22	0.77	4.46	0.028
Apodemus spp. ~ PC2	-72.18	0.22	3.58	0.081
***S. araneus* ~ PC1 + Distance + PC2**	-73.69	0.57	3.48	0.050
***C. suaveolens* ~ Distance + PC2**	-75.57	0.50	3.71	0.046
C. leucodon ~ PC1×Distance + PC2×Distance	-77.91	0.64	1.35	0.544
M. agrestis ~ PC1×Distance + PC2×Distance	-84.93	0.73	1.99	0.209

Drava River (DR) positively influenced the species' abundance in owl pellets compared to the Drava Floodplain (DFP) ($\beta = -0.065 \pm 0.029$, $t = 2.207$, $P = 0.048$) *(Figure 3A)*. Based on the determination coefficient, the same final model of the Field Vole *(Microtus agrestis)* demonstrated a significant impact of the distance categories on the abundance *(Table 3)*. The standardised regression coefficient demonstrated that area near the Drava River (DR) ($\beta = -0.090 \pm 0.031$, $t = 2.859$, $P = 0.014$) and the Mecsek and Tolna-Baranya

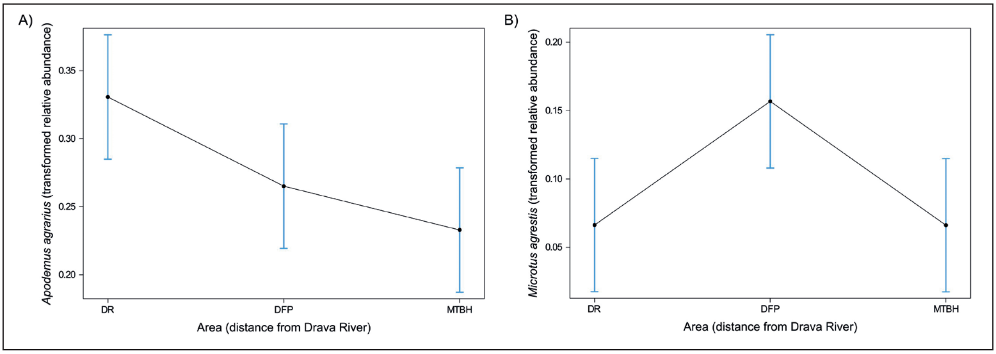


Figure 3. Impact of distance categories on the Striped Field Mouse's *(A. agrarius)* (A) and on the Field Vole's *(M. agrestis)* (B) abundance distribution
3. ábra A távolságkategóriák hatása a pirók erdeiegér *(A. agrarius)* (A) és a csalitjáró pocok *(M. agrestis)* (B) tömegességi eloszlására

hill country (MTBH) (β = -0.091 ± 0.032, t = 2.863, P = 0.014) negatively influenced the abundance of the Field Vole in the Common Barn-owls' food composition compared to the Drava Floodplain (DFP) *(Figure 3B)*.

Regarding the relationship between landscape metrics and small mammals' abundance at the species level, the best candidate model was significant for three species *(Table 3)*. The significant final model of the Striped Field Mouse included the main impact of distance categories and the first two PC scores of landscape metrics as well as the cumulative effect of PC1 score and distance categories (PC1×Distance) *(Table 3)*. Distance dependence as the main effect in this model also showed a similar result as in the land use evaluation, the variation in the Striped Field Mouse' abundance was negatively determined by the distance of the Mecsek and Tolna-Baranya hill country (MTBH) (β = -0.102 ± 0.043, t = 2.384, P = 0.044). As regards the interaction effect, the estimated regression coefficient demonstrated a significant positive relationship between PC1 scores and the quantity of the Striped Field Mouse in case of the Mecsek and Tolna-Baranya hill country (MTBH) (β = 0.145 ± 0.065, t = 2.367, P = 0.049) in contrast to the other two distance categories. Based on the correlation of the PC1 scores and the value of the landscape metrics *(Figure 4A)*, the results suggested that the proportion of the Striped Field Mouse in the diet of the Common

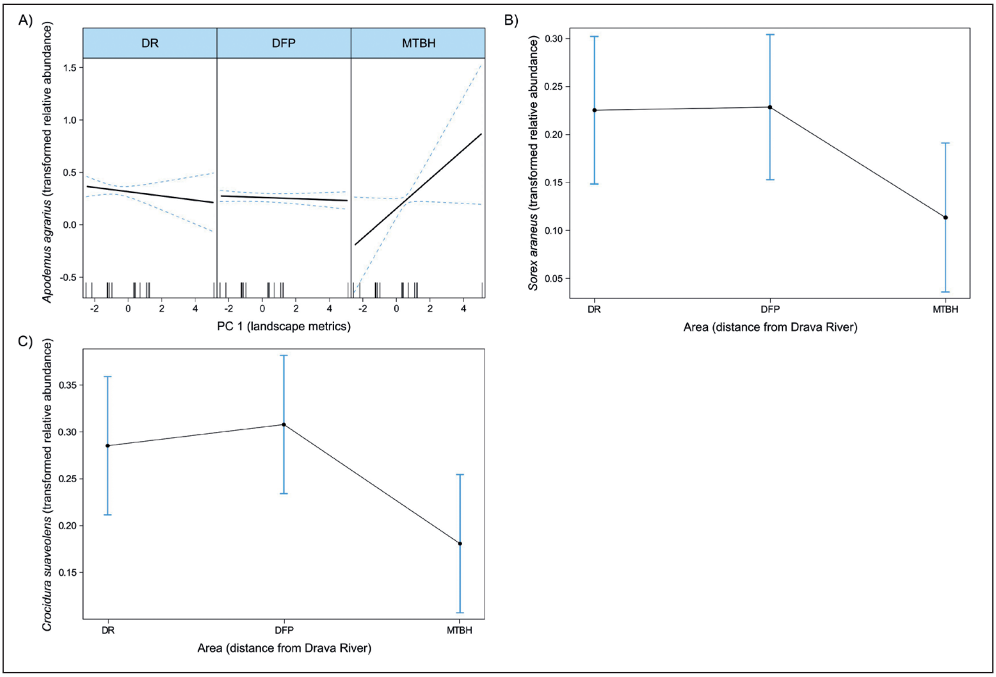


Figure 4. Interaction effect plot based on the relationship between the Striped Field Mouse's *(A. agrarius)* abundance and PC1 scores of landscape metrics (A) and the impact of distance categories on the Common Shrew's *(S. araneus)* (B) and on the Lesser White-toothed Shrew's *(C. suaveolens)* (C) abundance distribution

4. ábra A pirók erdeiegér *(A. agrarius)* és a PC1 főkomponens értékek közötti összefüggés interakciós ábrája (A), valamint a távolságkategóriák hatása az erdei cickány *(S. araneus)* (B) és a keleti cickány *(C. suaveolens)* (C) abundanciájára

Barn-owls was influenced by the increase in the mean of perimeter/area ratio and the mean of the contiguity index (CONTIG_MN), which determined the patch shape complexity. In addition, the final models were significant for two of the three studied shrew species. In case of the Common Shrew *(Sorex araneus)*, the best candidate model included distance categories, and PC1 and PC2 scores of the landscape metrics as main effects *(Table 3)*. According to the estimated standardised coefficient, the abundance distribution of this species was negatively influenced by the Mecsek and Tolna-Baranya hill country (MTBH) (β = -0.115 ± 0.049, t = 2.343, P = 0.041) *(Figure 4B)*. This distance-dependent effect can be interpreted in relation to the area of the Drava Floodplain. The stepwise regression analysis supported similar results also in case of Lesser White-toothed Shrew *(Crocidura suaveolens)*. The significant final model included distance categories as nominal and PC2 scores of landscape metrics as continuous predictors *(Table 3)*, of which the distance effect from the Drava River was significant in the model. Based on the significant estimated parameter, the abundance variation of this shrew species was negatively influenced by the area of the Mecsek and Tolna-Baranya hill country (MTBH) compared to the Drava Floodplain (DFP) (β = -0.112 ± 0.046, t = 2.398, P = 0.035) *(Figure 4C)*.

Considering the results of the forward selection regression method at the genus and derived index (TLI, MMR) level, in the case of the relationship between land use and response variables, two significant final models were detected by the analysis. The best model of the *Crocidura* genus included only the PC1 scores of the land use variables. Despite the fact that this final model explained a smaller proportion of the total variance, based on the significance of the R^2 value, we interpreted the results of this model *(Table 4)*. The estimated regression coefficient showed the significant relationship between PC1 scores of land use and quantity distribution of this shrew group (β = 0.049 ± 0.035, t = 2.240, P = 0.043). Based on the correlation between PC scores and land use categories,

Table 4. Final models of linear regression analysis at genus level (significant models are in bold)
4. táblázat A lineáris regresszió végső modelljei a genusok szintjén (a szignifikáns modellek félkövéren szerepelnek a táblázatban)

Small mammal genus / Final model	**Model parameters**			
	AIC	**R^2**	**F**	**P**
Land use				
Sorex ~ PC1× Distance + PC2×Distance	-65.13	0.67	1.52	0.315
***Crocidura* ~ PC1**	**-68.48**	**0.34**	**4.38**	**0.048**
Apodemus ~ PC1×Distance + PC2×Distance	-78.78	0.74	2.18	0.179
MMR ~ PC1×Distance + PC2×Distance	-14.10	0.43	0.58	0.769
TLI ~ PC1×Distance + PC2×Distance	**-66.34**	**0.82**	**4.91**	**0.036**
Landscape metrics				
***Sorex* ~ Distance + PC2**	**-69.14**	**0.51**	**3.76**	**0.044**
***Crocidura* ~ Distance + PC2**	**-69.52**	**0.45**	**3.64**	**0.048**
Apodemus ~ PC1 + Distance + PC1×Distance	-72.42	0.42	1.28	0.351
TLI ~ Distance	**-60.21**	**0.39**	**3.89**	**0.050**

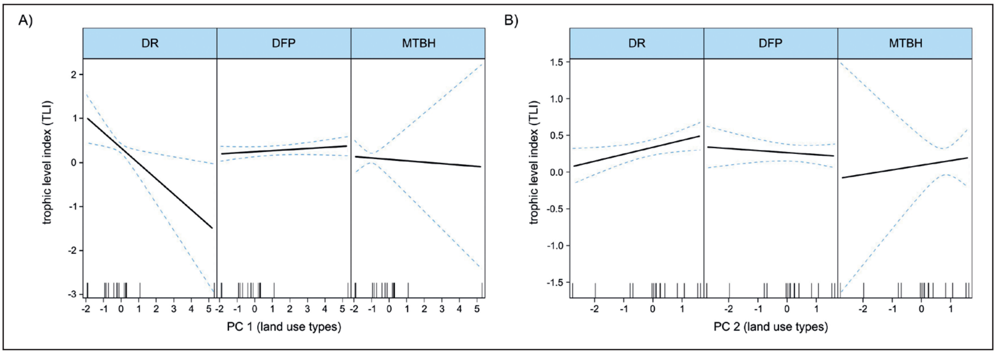


Figure 5. Interaction effect plot based on the relationship between the values of trophic level index (TLI) and PC1 scores (A) as well as TLI and PC2 scores of land use variables (B) compared between different distances from the Drava River

5. ábra A trofikus index (TLI) és a PC1 főkomponens értékek (A), valamint a trofikus index és a PC2 főkomponens értékek közötti összefüggés interakciós ábrái, összehasonlítva a Drávától mért különböző távolságkategóriákat

this result supported that the hunting success of these drought tolerant shrew species was influenced by the increasing proportion of grasslands and pastures, and the decrease in crop area proportion in the local landscapes. As regards of the derived indices, the final model of TLI included two cumulative effects of PC scores and distance categories (PC1×Distance, PC2×Distance). This best candidate model was significant, because the interaction of predictor variables explained more than 80% of the total variance *(Table 4)*. The estimated regression coefficient of the interaction effect showed a significant negative relationship between PC1 scores and the value of TLI in case of the area near the Drava River (DR) (β = -0.365 ± 0.114, t = 3.219, P = 0.018) *(Figure 5A)*, and a positive relationship between PC2 scores and the value of TLI in case of the area near the Drava River (DR) in contrast to the other two distance categories (β = 0.125 ± 0.051, t = 2.469, P = 0.049) *(Figure 5B)*. The PC1 scores of land use were positively correlated with the forest, pasture, and grassland proportions, and negatively associated with the

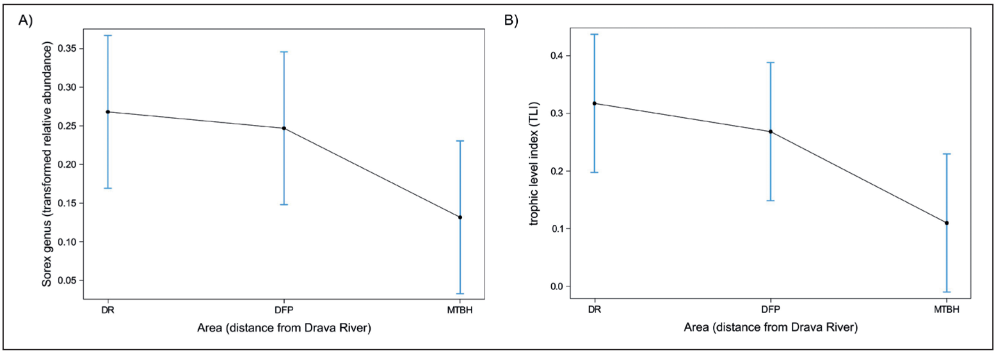


Figure 6. Impact of distance categories on the *Sorex* genus' abundance distribution (A) and on the distribution of the values of trophic level index (TLI) (B)

6. ábra A távolságkategóriák hatása a *Sorex* genus abundancia eloszlására (A) és a trofikus index (TLI) értékeinek eloszlására (B) proportion of croplands. According to this, the value of TLI was negatively influenced by the decrease in crop patches and the increase in pasture and grassland area, which land use types facilitate the distribution of insectivores. In case of the other interaction, PC2 scores of land use were positively associated with the proportion of cropland areas and negatively correlated with the relative frequency of wetland and urban patches in the local landscapes. Therefore, the significant regression in the case of the second interaction shows that the variation of TLI values were positively influenced by the increase in cropland areas and negatively associated with the decreasing proportion of wetland and built-up surface areas, all of which determines the availability of rodent and shrew prey.

Considering the effect of landscape metrics at genus and derived index level, the significant final model was selected by the forward stepwise regression method in case of three response variables. In the case of the *Sorex* genus, the best candidate model included distance categories and PC2 scores of landscape metrics as main effects, explaining 51% of the total variance. Based on the distance from the Drava River, the estimated regression parameter showed that the abundance distribution of this shrew group was negatively influenced by the Mecsek and Tolna-Baranya hill country (MTBH) compared to the Drava Floodplain ($\beta = -0.142 \pm 0.057$, $t = 2.457$, $P = 0.032$) *(Figure 6A)*. Similarly, a significantly negative relationship was detected between the PC2 scores of landscape metrics and the abundance of *Sorex* genus by the regression analysis ($\beta = -0.037 \pm 0.017$, $t = 2.124$, $P = 0.057$). The significant final model of the *Crocidura* genus included the PC2 scores and the distance categories similarly as in the previous prey group *(Table 4)*. In this case, the regression method did not confirm the distance dependence, while based on the estimated regression coefficient, a significant positive relationship was detected between PC2 scores and the relative frequency of the *Crocidura* genus ($\beta = 0.052 \pm 0.019$, $t = 2.314$, $P = 0.041$). In addition, in the case of the TLI values, the multiple regression method confirmed the significant distance effect from the Drava River. The Mecsek and Tolna-Baranya hill country (MTBH) negatively influenced the TLI values compared to the Drava Floodplain (DFP) ($\beta = -0.159 \pm 0.078$, $t = 2.354$, $P = 0.049$) *(Figure 6B)*.

Discussion

In this paper, we studied the food composition of Common Barn-owls at different distances from the Drava River. The diet of this nocturnal raptor varies in different landscape types and land use (Trejo & Lambertucci 2007, Charter *et al.* 2009, Hindmarch & Elliot 2015, Milchev 2015, Horváth *et al*. 2018), however, the small mammals are the main prey group for Common Barn-owl (Marti 1988, Durant *et al.* 2013, Romano *et al.* 2020). In our study, we also found that small mammals were a significant part of the owls' food composition at all three distances (>98%). Among the small mammals, rodents were dominant in the diet, and the abundance of this prey group was significantly higher in Mecsek and Tolna-Baranya hill country than near the Drava River, because the open landscapes such as agrarian areas are advantageous for habitat generalist prey species like the Common Vole or *Mus* species (Millán de la Peña *et al.* 2003, Baláž *et al.* 2013, Milchev 2015, Veselovský *et al.*

2017). On the contrary, the quantity of shrews in the food composition was significantly higher along the Drava River. This area is heterogeneous and rich in semi-natural habitats and wetlands, and a greater diversity of the landscape is beneficial to the occurrence of rare species such as shrews (Milchev 2015, Veselovský *et al.* 2017, Horváth *et al.* 2018, 2022). Based on the above and as already described in several studies, habitat quality and landscape structure are important factors in determining the food composition of the Common Barn-owl because these features influence the availability of the prey (Milchev 2015, Szép *et al.* 2017).

Common Barn-owls occasionally consume non-mammalian prey like birds and frogs, but these species are insignificant in the owls' diet (Milchev 2015, Roulin 2015, Szép *et al.* 2017, Moysi *et al.* 2018). Higher bird consumption can be observed in heterogeneous landscapes with larger and more diverse vegetation cover than in uniform arable lands (Møller 1984, Hanowski *et al.* 1997, Moreira *et al.* 2005, Charter *et al.* 2009). Nevertheless, we could not detect a significant difference in the proportion of birds in the food composition at the three different distances, despite these areas being different in landscape characteristics. Common Barn-owl hunt a higher proportion of anurans at riverbanks (Rocha *et al.* 2011) and during periods when the availability of rodents decreases, because owls respond to lower numbers of rodents by changing their diet and can consume more anurans (Hodara & Poggio 2016), as we have shown in the areas near the Drava River.

According to our results, Shannon (H) and Simpson (1-D) diversity are significantly higher near the Drava River and in the Drava Floodplain than in the Mecsek and Tolna-Baranya hill country, characterised by the highest level of agricultural cultivation. This is coherent with several studies, in which it has been described that heterogeneous environmental conditions and semi-natural patches provide more habitats and resources, and as a result, species richness and diversity increase (Tews *et al.* 2004, Billeter *et al.* 2008), while the increase in agricultural cultivation causes the loss of biodiversity (Benton *et al.* 2003, Millán de la Peña *et al.* 2003, Gentili *et al.* 2014).

Based on the result of ANOVA and multiple regression, the distance from the Drava River proved to be an important predictor variable in the quantity distribution of Striped Field Mouse. This species is well adapted to a variety of habitats (Kozakiewicz *et al.* 1999, Łopucki *et al.* 2013, Gentili *et al.* 2014,), though, as previously described, it is more common in natural, semi-natural, and heterogeneous areas than in homogeneous, simplified landscapes (Fischer & Schröder 2014, Gentili *et al.* 2014). Our result is consistent with these studies, because the abundance of Striped Field Mouse was the highest near the Drava River, where there are more natural, semi-natural and heterogeneous habitats than further north from the river. This is also supported by the analysis at landscape metrics level in the case of the Mecsek and Tolna-Baranya hill country, as we have shown that the abundance of this species declines with the decrease of patch diversity in this area.

Based on the result of multiple linear regression, the three distance categories were also a determining factor of the abundance of the Field Vole, because it was detected in the highest proportion in the floodplain and the other two distance categories significantly negatively affected the distribution of the abundance of the Field Vole. It is a general belief that this *Microtus* species lives in open areas like meadows, grasslands, clear cuts, dunes and moorlands (Alibhai & Gipps 1991, Borowski 2003, Horváth 2007, Kryštufek *et al.* 2008, Szép *et al.* 2017), but it also occurs in hedgerows, woodlands and forests (Hansson 1977, Kowalski & Ruprecht 1981, Alibhai & Gipps 1991, Kryštufek *et al.* 2008). Agricultural landscapes, field margins, unlike cropped areas, can be important habitats for field voles (Tattersall *et al.* 2002, Broughton *et al.* 2014) because they provide them with sufficient resources (Yletyinen & Norrdahl 2008) and connect patches that may be suitable habitats for this species (Renwick & Lambin 2011). This is also supported by our results, because in the Drava Floodplain, where the species is most frequent, there are many natural, semi-natural open areas and also agricultural areas, thus, the variety of landscape types provides a suitable habitat for the species.

In case of *Crocidura* genus, the results of multiple linear regression at land use and landscape metrics level are consistent with each other. The amount of forests, grass and pastures in the owl hunting area had a positive, while the proportion of cropped areas a negative effect on the abundance of white-toothed shrews. The latter is related to the result that the Mecsek and Tolna-Baranya hill country dominated by agricultural areas also negatively affect the frequency of the Lesser White-toothed Shrew. Several studies have revealed that *Crocidura* species prefer open, dry grassy areas (Bosé & Guidali 2001, Bego *et al.* 2008, Fischer *et al.* 2011, Paspali *et al.* 2013, Szép *et al.* 2019), but are less frequently associated with forest edges and forests as described in Moravia (Suchomel & Heroldová 2004, Suchomel & Purchart 2011), Slovakia (Lešo *et al.* 2008) and also Romania (Barti 2011). Based on the results of the land use level analysis, cultivated areas have a negative effect on the abundance of the *Crocidura* genus, which contradicts some studies in which the possible positive effect of agricultural areas on the abundance of this species has been highlighted (Bosé & Guidali 2001, Heroldová *et al.* 2007, Veselovský *et al.* 2017). The structure of the landscape is also a determining factor in the occurrence of a species, we found a positive relationship between the mean patch shape complexity, mean fractal dimension, patch richness and the frequency of *Crocidura* shrews, which means that heterogeneous habitats are more favorable for these species. Szép *et al.* (2017) showed the opposite, as during their work in the south-western part of Hungary, they found that the abundance of the Lesser White-toothed Shrew was higher in homogenous landscapes.

The Common Shrew and the Pygmy Shrew *(Sorex minutus)* can be found in most habitat types (Tattersall *et al.* 2002, Heroldová *et al.* 2007, Wang & Grimm 2007, Mortelliti & Boitani 2009, Hutterer & Kryštufek 2016, Hutterer *et al.* 2016), based on which we would expect that land use and landscape composition will not have an important effect. Although ANOVA did not show a significant difference in comparing the three distance categories, the Mecsek and Tolna-Baranya hill country had a negative effect on the abundance of both the Common Shrew and the *Sorex* genus, based on the result of multiple regression analysis. This can be explained by the fact that human-made landscape modification (Love *et al.* 2000, Balestrieri *et al.* 2019) and intensive agricultural farming (Suchomel & Heroldová 2004, Heroldová *et al.* 2007) caused the decline of these species. In the case of landscape metrics, the opposite effect was shown for *Crocidura* species. Based on multiple regression analysis, there is a negative relationship between the SHAPE_MEAN, FRAC and PR landscape metrics and the abundance of *Sorex* species, so as the landscape complexity increases, the occurrence of these species decreases. This is consistent with the finding of Fisher *et al.* (2011). They have shown that the Common Shrew disappear in complex landscapes.

The trophic level index expresses the importance of shrews, and the abundance of these species is influenced by the quality of their habitat and the landscape structure (Paspali *et al.* 2013, Szép *et al.* 2017, Veselovský *et al.* 2017). This finding is also supported by our results, according to which the value of the index significantly differed in the comparison of the three distance categories characterised by different landscape patterns. Based on our multiple regression analysis at the land use level, the Mecsek and Tolna-Baranya hill country dominated by agrarian lands had a negative impact on the value of TLI. The intensification of agriculture (e.g. mechanical agriculture, use of chemical products) caused the landscape to become simpler and more homogeneous and the habitat quality to decline (Contoli 1980, Battersby 2005, Michel *et al.* 2006, Balestrieri *et al.* 2019, Battisti *et al.* 2019), which led to a decrease in the number of shrews and an increase in the number of rodents linked to agriculture. In case of the Drava River, there is a positive relationship between most of the landscape metrics describing the complexity and diversity of the landscape and the TLI. Therefore, the regression analysis reaffirmed that the landscape structure also plays a key role in the composition of small mammal communities and thus, in the relative proportion of insectivores and rodents in the diet of barn-owls.

The results suggest that on a landscape scale, the composition and structure of the landscape influences prey occurrence in owl hunting areas and the frequency-dependent availability of each prey species and categories, which determines the food niche pattern of owls in space and time. In order to reveal further details of the landscape dependence of the Common Barn-owl feeding pattern, additional studies are needed on several spatial scales, based on higher sampling effort.

Acknowledgement

The Common Barn-owls' pellet analysis was carried out with the support of Duna-Dráva National Park Directorate and the Hungarian Biodiversity Monitoring System. Thanks to László Bank, secretary of the Baranya County Group of BirdLife Hungary for providing the pellet samples. We thank the volunteers and university students for their dedicated work in helping us disassemble and process the owl pellets. Finally, we would like to thank the two reviewers for many helpful comments.

References

Alibhai, S. K. & Gipps, J. H. W. 1991. Field Vole *Microtus agrestis*. – In: Corbet, G. B. & Harris, S. (eds.) The Handbook of British Mammals. – Blackwell Scientific Publications, London, pp. 203–208.

Andries, A. M., Gulinck, H. & Herremans, M. 1994. Spatial modelling of the Barn Owl *Tyto alba* habitat using landscape characteristics derived from SPOT data. – Ecography 17: 278–287. DOI: 10.1111/j.1600-0587.1994.tb00104.x

Askew, N. P., Searle, J. B. & Moore, N. P. 2007. Agri-environment schemes and foraging of Barn Owls *Tyto alba*. – Agriculture, Ecosystems & Environment 118(1): 109–114. DOI: 10.1016/j.agee.2006.05.003

Baláž, I., Ambros, M., Tulis, F., Veselovský, T., Klimant, P. & Augustiničová, G. 2013. Hlodavce a hmyzožravce Slovenska [Rodents and insectivores of Slovakia]. – FPV UKF, Nitra, edícia Prírodovedec č. 547 [FNS KFU, edition Prírodovedec č. 547] Nitra

Balestrieri, A., Gazzola, A., Formenton, G. & Canova, L. 2019. Long-term impact of agricultural practices on the diversity of small mammal communities: a case study based on owl pellets. – Environmental Monitoring and Assessment 191(12): 1–14. DOI: 10.1007/s10661-019-7910-5

Barti, L. 2011. Unusual occurrence of the Bicoloured White-toothed Shrew (*Crocidura leucodon*, Soricomorpha: Soricidae) in a mature beech forest in the Ciomad-Puturosu Mountains (Eastern Carpathians, Central Romania). – Acta Siculica 2011: 119–124.

Battersby, J. 2005. UK Mammals: Species Status and Population Trends. First Report by the Tracking Mammals Partnership. – JNCC/Tracking Mammals Partnership

Battisti, C., Dodaro, G., Di Bagno, E. & Amori, G. 2019. Small mammal assemblages in land-reclaimed areas: do historical soil use changes and recent anthropisation affect their dominance structure? – Ethology, Ecology & Evolution 32(3): 282–288. DOI: 10.1080/03949370.2019.1693433

Bego, F., Kryštufek, B., Paspali, G. & Rogozi, E. 2008. Small terrestrial mammals of Albania: annotated list and distribution. – Hystrix 19(2): 83–101.

Benton, T. G., Vickery, J. A. & Wilson, J. D. 2003. Farmland biodiversity: is habitat heterogeneity the key? – Trends in ecology and evolution 18(4): 182–188. DOI: 10.1016/S0169-5347(03)00011-9

Billeter, R., Liira, J., Bailey, D., Bugter, R. & Arens, P. 2008. Indicators for biodiversity in agricultural landscapes: a pan-European study. – Journal of Applied Ecology 45(1): 141–150. DOI: 10.1111/j.1365-2664.2007.01393.x

Bond, G., Burnside, N. G., Metcalfe, D. J., Scott, D. M. & Blamire, J. 2005. The effects of land-use and landscape structure on Barn Owl *(Tyto alba)* breeding success in southern England, UK. – Landscape Ecology 20(5): 555–566. DOI: 10.1007/s10980-004-5037-7

Borowski, Z. 2003. Habitat selection and home range size of Field Voles *Microtus agrestis* in Słowiński National Park, Poland. – Acta Theriologica 48(3): 325–333. DOI: 10.1007/BF03194172

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

Bossard, M., Feranec, J. & Otahel, J. 2000. CORINE land cover technical guide – Addendum 2000. Technical Report No 40, European Environmental Agency

Broughton, R. K., Shore, R. F., Heard, M. S., Amy, S. R. & Meek, W. R. 2014. Agri-environment scheme enhances small mammal diversity and abundance at the farm-scale. – Agriculture, Ecosystem & Environment 192: 122–129. DOI: 10.1016/j.agee.2014.04.009

Burel, F., Butet, A., Delettre, Y. R. & Millán de la Peña, N. 2004. Differential response of selected taxa to landscape context and agricultural intensification. – Landscape and Urban Planning 67(1): 195–204. DOI: 10.1016/S0169-2046(03)00039-2

Charter, M., Izhaki, I., Meyrom, K., Motro, Y. & Leshem, Y. 2009. Diets of Barn Owls differ in the same agricultural region. – The Wilson Journal of Ornithology 121(2): 378–383. DOI: 10.1676/08-083.1

Chao, A., Gotelli, N. J., Hsieh, T. C., Sander, E. L., Ma, K. H., Colwell, R. K. & Ellison, A. M. 2014. Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. – Ecological Monographs 84(1): 45–67. DOI: 10.1890/13-0133.1

Colvin, B. A. 1985. Common Barn-owl population decline in Ohio and the relationship to agricultural trends. – Journal of Field Ornithology 56(3): 224–235.

Colwell, R. K. & Elsensohn, J. E. 2014. EstimateS turns 20: statistical estimation of species richness and shared species from samples, with non-parametric extrapolation. – Ecography 37(6): 609–613. DOI: 10.1111/ecog.00814

Contoli, L. 1980. Borre di Strigiformi e ricerca teriologica in Italia [Owl pellet analysis and theriological research in Italy]. – Natura e montagna 3: 73–94. (in Italian)

Durant, J. M., Hjermann, D. Ø. & Handrich, Y. 2013. Diel feeding strategy during breeding in male Barn Owls *(Tyto alba)*. – Journal of Ornithology 154(3): 863–869. DOI: 10.1007/s10336-013-0956-1

Environmental Systems Research Institute (ESRI) 2012. ArcGIS Desktop Software, Release 10.1. – Redlands

European Environmental Agency 2007. Land-use scenarios for Europe: qualitative and quantitative analysis on a European scale. – EEA Technical report No 9/2007, European Environmental Agency

Fischer, C. & Schröder, B. 2014. Predicting spatial and temporal habitat use of rodents in a highly intensive agricultural area. – Agriculture, Ecosystem & Environment 189: 145–153. DOI: 10.1016/j.agee.2014.03.039

Fischer, C., Thies, C. & Tscharntke, T. 2011. Small mammals in agricultural landscapes: opposing responses to farming practices and landscape complexity. – Biological Conservation 144(3): 1130–1136. DOI: 10.1016/j.biocon.2010.12.032

Frey, C., Sonnay, C., Dreiss, A. & Roulin, A. 2011. Habitat, breeding performance, diet and individual age in Swiss Barn Owls *(Tyto alba)*. – Journal of Ornithology 152(2): 279–290. DOI: 10.1007/s10336-010-0579-8

Geiger, F., Bengtsson, J., Berendse, F., Weisser, W. W. & Emmerson, M. 2010. Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. – Basic and Applied Ecology 11(2): 97–105. DOI: 10.1016/j.baae.2009.12.001

Gentili, S., Sigura, M. & Bonesi, L. 2014. Decreased small mammals species diversity and increased population abundance along a gradient of agricultural intensification. – Hystrix 25(1): 39–44.

Gorman, M. L. & Reynolds, P. 1993. The impact of land-use change on voles and raptors. – Mammal Review 23: 121–126. DOI: 10.1111/j.1365-2907.1993.tb00423.x

Hanowski, J. M., Niemi, G. J. & Christian, D. C. 1997. Influence of within-plantation heterogeneity and surrounding landscape composition on avian communities in hybrid poplar plantations. – Conservation Biology 11: 936–944. DOI: 10.1046/j.1523-1739.1997.96173.x

Hansson, L. 1977. Spatial dynamics of Field Voles *Microtus agrestis* in heterogeneous landscapes. – Oikos 29: 539–544. DOI: 10.2307/3543592

Heroldová, M., Bryja, J., Zejda, J. & Tkadlec, E. 2007. Structure and diversity of small mammal communities in agriculture landscape. – Agriculture, Ecosystem & Environment 120(2–4): 206–210. DOI: 10.1016/j.agee.2006.09.007

Hindmarch, S. & Elliott, J. E. 2015. A specialist in the city: the diet of Barn Owls along a rural to urban gradient. – Urban Ecosystem 18(2): 477–488. DOI: 10.1007/s11252-014-0411-y

Hindmarch, S., Krebs, E. A., Elliott, J. E. & Green, D. J. 2012. Do landscape features predict the presence of Brn Owls in a changing agricultural landscape? – Landscape and Urban Planning 107(3): 255–262. DOI: 10.1016/j.landurbplan.2012.06.010

Hodara, K. & Poggio, S. L. 2016. Frogs taste nice when there are few mice: do dietary shifts in Barn Owls result from rapid farming intensification? – Agriculture, Ecosystems & Environment 230: 42–46. DOI: 10.1016/j.agee.2016.05.027

Horváth, G. F. 2000. Comparative analysis of the small mammal fauna of the river Drava plain region. I. Species richness, diversity and biomass based on the analysis of Barn Owl *Tyto alba* (Scop., 1769) pellets. – Tiscia 32: 47–53.

Horváth, G. F. 2007. Csalitjáró pocok *Microtus agrestis* [Field vole *Microtus agrestis*]. – In: Bihari, Z., Csorba, G. & Heltai, M. (eds.) Magyarország emlőseinek atlasza [Atlas of the Hungarian Mammals]. – Kossuth Kiadó, Budapest, pp. 160–161. (in Hungarian)

Horváth, G. F. 1998. Kisemlős (Mammalia) faunisztikai vizsgálatok a gyöngybagoly *(Tyto alba)* köpetanalízise alapján a Dráva mentén (1995–1997) [The investigation of the small mammal fauna of the River Dráva plain region, based on the analysis of Brn Oowl *(Tyto alba)* pellets between 1995–1997.]. – Dunántúli Dolgozatok Természettudományi Sorozat 9: 475–488. (in Hungarian with English Summary)

Horváth, A., Morvai, A. & Horváth, G. F. 2018. Food-niche pattern of the Barn Owl *(Tyto alba)* in intensively cultivated agricultural landscape. – Ornis Hungarica 26(1): 27–40. DOI: 10.1515/orhu-2018-0002

Horváth, A., Morvai, A. & Horváth, G. F. 2022. Difference in small mammal assemblages in the diet of the Common Barn-owl *Tyto alba* between two landscapes. – Acta Zoologica Academiae Scientiarum Hungaricae 68(2): 189–216. DOI: 10.17109/AZH.68.2.189.2022

Horváth, G. F., Molnár, D., Németh, T. & Csete, S. 2005. Landscape ecological analysis of Barn Owl pellet data from the Drava lowlands, Hungary. – Natura Somogyiensis 7: 179–189. DOI: 10.24394/NatSom.2005.7.179

Hsieh, T. C., Ma, K. H. & Chao, A. 2016. iNEXT: an R package for rarefaction and extrapolation of species diversity (Hill numbers). – Methods in Ecology and Evolution 7(12): 1451–1456. DOI: 10.1111/2041-210X.12613

Hutterer, R. & Kryštufek, B. 2016. *Sorex araneus*, The IUCN Red List of Threatened Species. – https://www.iucnredlist.org/species/29661/115170489.

Hutterer, R., Kryštufek, B., Fernandes, M. & Meinig, H. 2016. *Sorex minutus*, The IUCN Red List of Threatened Species. – https://www.iucnredlist.org/species/29667/115171222.

Iannella, M., Liberatore, L. & Biondi, M. 2016. The effects of a sudden urbanization on micromammal communities: a case study of post-earthquake L'Aquila (Abruzzi Region, Italy). – Italian Journal of Zoology 83(2): 255–262. DOI: 10.1080/11250003.2016.1149235

Jacob, J., Manson, P., Barfknecht, R. & Fredricks, T. 2014. Common Vole *(Microtus arvalis)* ecology and management: implications for risk assessment of plant protection products. – Pest Management Science 70(6): 869–878. DOI: 10.1002/ps.3695

Jaksić, F. M., Seib, R. L. & Herrera, C. M. 1982. Predation by the Barn Owl *(Tyto alba)* in Mediterranean habitats of Chile, Spain and California: A comparative approach. – The American Midland Naturalist 107(1): 151–162. DOI: 10.2307/2425196

Jost, L. 2006. Entropy and diversity. – Oikos 113(2): 363–375. DOI: 10.1111/j.2006.0030-1299.14714.x

Kessler, J. E. 2015. Osteological guide of songbirds from Central Europe. – Ornis Hungarica 23(2): 62–155. DOI: 10.1515/orhu-2015-0016

Klein, R. G. & Cruz-Uribe, K. 1984. The analysis of animal bones from archeological sites. – University of Chicago, Chicago

Kowalski, K. & Ruprecht, A. L. 1981. The Field Vole *(Microtus agrestis)*. – In: Pucek, Z. (ed.) Keys to vertebrates of Poland, Mammals. – Polish Scientific Publishers, Warsaw, pp. 189–190.

Kozakiewicz, M., Gortat, T., Kozakiewicz, A. & Barkowska, M. 1999. Effects of habitat fragmentation on four rodent species in a Polish farm landscape. – Landscape Ecology 14(4): 391–400. DOI: 10.1023/A:1008070610187

Kryštufek, B. & Macholán, M. 1998. Morphological differentiation in *Mus spicilegus* and the taxonomic status of mound-building mice from the Adriatic coast of Yugoslavia. – Journal of Zoology 245(2): 185–196. DOI: 10.1111/j.1469-7998.1998.tb00086.x

Kryštufek, B., Voharalík, V., Zima, J. & Zagorodnyuk, I. 2008. *Microtus agrestis*, The IUCN Red List of Threatened Species. – https://www.iucnredlist.org/species/13426/115112050.

Lešo, P., Le, O. & Kropil, R. 2008. Unusual occurrence of the Bicoloured White-toothed Shrew *(Crocidura leucodon)* in a fir-beech forest in central Slovakia (Soricomorpha: Soricidae). – Lynx 39(1): 191–194.

Leveau, L. M., Teta, P., Bogdaschewsky, R. & Pardiñas, U. F. J. 2006. Feeding habits of the Barn Owl *(Tyto alba)* along a longitudinal-latitudinal gradient in central Argentina. – Ornitologia Neotropical 17(3): 353–362.

Łopucki, R., Mróz, I., Berliński, Ł. & Burzych, M. 2013. Effects of urbanization on small-mammal communities and the population structure of synurbic species: an example of a medium-sized city. – Canadian Journal of Zoology 91(8): 554–561. DOI: 10.1139/cjz-2012-0168

Love, R. A., Webon, C., Glue, D. E., Harris, S. & Harris, S. 2000. Changes in the food of British Barn Owls *(Tyto alba)* between 1974 and 1997. – Mammal Review 30(2): 107–129. DOI: 10.1046/j.1365-2907.2000.00060.x

Lyman, R. L. 2012. Rodent-prey content in long-term samples of Barn Oowl *(Tyto alba)* pellets from the northwestern United States reflects local agricultural change. – The American Midland Naturalist 167(1): 150–163. DOI: 10.1674/0003-0031-167.1.150

Macholán, M. 1996. Multivariate morphometric analysis of European species of the genus *Mus* (Mammalia, Muridae). – Zeitschrift fur Saugetierkunde 61: 304–319.

Marti, C. D. 1988. A long-term study of food-niche dynamics in the Common Barn-owl: comparisons within and between populations. – Canadian Journal of Zoology 66(8): 1803–1812. DOI: 10.1139/z88-261

Marti, C. D. 2010. Dietary trends of Barn Owls in an agricultural ecosystem in northern Utah. – The Wilson Journal of Ornithology 122: 60–67. DOI: 10.1676/09-025.1

Martin, J. M., Branch, L. C., Raid, R. N. & Beyeler, S. C. 2010. Temporal instability of agricultural habitat reduces reproductive success of Barn Owls *(Tyto alba)*. – The Auk 127(4): 909–916. DOI: 10.1525/auk.2010.09211

Martínez, J. A. & Zuberogoitia, I. 2004. Habitat preferences and causes of population decline for Barn Owls *Tyto alba*: a multi-scale approach. – Ardeola 51(2): 303–317.

März, R. 1972. Gewöll- und Rupfungskunde [The science of pellets and pluck]. – Akademie Verlag, Berlin (in German)

Mazzotti, S. & Caramori, G. 1998. Analysis of small mammal communities in south-eastern Po Valley. – Gortania Atti Museo Friulano Storia Naturale 20: 253–262.

McGarigal, K. 2015. Fragstats help version 4.2. – http://www.umass.edu/landeco/research/fragstats/documents/fragstats.help.4.2.pdf.

McGarigal, K., Cushman, S. A. & Ene, E. 2012. FRAGSTATS v4: Spatial pattern analysis program for categorical and continuous maps. – http://www.umass.edu/landeco/research/fragstats/fragstats.html.

Meek, W. R., Burman, P. J., Nowakowski, M., Sparks, T. H. & Burman, N. J. 2003. Barn Owl release in lowland southern England – a twenty-one year study. – Biological Conservation 109(2): 271–282. DOI: 10.1016/S0006-3207(02)00155-6

Meek, W. R., Burman, P. J., Sparks, T. H., Nowakowski, M. & Burman, N. J. 2012. The use of Barn owl *Tyto alba* pellets to assess population change in small mammals. – Bird Study 59(2): 166–174. DOI: 10.1080/00063657.2012.656076

Meyrom, K., Motro, Y., Leshem, Y., Aviel, S., Izhaki, I., Argyle, F. & Charter, M. 2009. Nest-box use by the Barn Owl *Tyto alba* in a biological pest control program in the Beit She'an valley, Israel. – Ardea 97(4): 463–467. DOI: 10.5253/078.097.0410

Michel, N., Burel, F. & Butet, A. 2006. How does landscape use influence small mammal diversity, abundance and biomass in hedgerow networks of farming landscapes? – Acta Oecologica 30(1): 11–20. DOI: 10.1016/j.actao.2005.12.006

Mikkola, H. 1983. Owls of Europe. – T. & AD. Poyser, Carton

Milchev, B. 2015. Diet of Barn Owl *Tyto alba* in Central South Bulgaria as influenced by landscape structure. – Turkish Journal of Zoology 39(5): 933–940. DOI: 10.3906/zoo-1409-24

Millán de la Peña, N., Butet, A., Delettre, Y., Paillat, G., Morant, P., Le Du, L. & Burel, F. 2003. Response of the small mammal community to changes in western French agricultural landscapes. – Landscape Ecology 18(3): 265–278. DOI: 10.1023/A:1024452930326

Møller, A. P. 1984. Community structure of birds in agricultural areas in summer and winter in Denmark. – Ecography 7: 413–418. DOI: 10.1111/j.1600-0587.1984.tb01142.x

Moreira, F., Beja, P., Morgado, R., Reino, L., Gordinho, L., Delgado, A. & Borralho, R. 2005. Effects of field management and landscape context on grassland wintering birds in southern Portugal. – Agriculture, Ecosystems & Environment 109: 59–74. DOI: 10.1016/j.agee.2005.02.011

Mortelliti, A. & Boitani, L. 2009. Distribution and coexistence of shrews in patchy landscapes: a field test of multiple hypotheses. – Acta Oecologica 35(6): 797–804. DOI: 10.1016/j.actao.2009.07.006

Moysi, M., Christou, M., Goutner, V., Kassinis, N. & Iezekiel, S. 2018. Spatial and temporal patterns in the diet of Barn Owl *(Tyto alba)* in Cyprus. – Journal of Biological Research-Thessaloniki 25(1): 1–8. DOI: 10.1186/s40709-018-0080-8

Niethammer, J. & Krapp, F. 1978. Handbuch der säugetiere Europas. – Teil 1, Nagetiere 1 [Handbook of the Mammals of Europe. – Part 1, Rodents 1]. – Akademische Verlagsgesellschaft, Wiesbaden (in German)

Niethammer, J. & Krapp, F. 1982. Handbuch der Säugetiere Europas – Teil 2, Nagetiere 2 [Handbook of Mammals of Europe – Part 2, Rodents 2]. – Akademische Verlagsgesellschaft, Wiesbaden (in German)

Niethammer, J. & Krapp, F. 1990. Handbuch der Säugetiere Europas – Teil 3, Insektenfresser, Herrentiere [Handbook of Mammals of Europe – Part 3, Insectivores, Primates]. – Akademische Verlagsgesellschaft, Wiesbaden (in German)

Paspali, G., Oruci, S., Koni, M., Wilson, I., Kryštufek, B. & Bego, F. 2013. Seasonal variation of small mammals in the diet of the Barn Owl *(Tyto alba)* in the Drinos River valley, southern Albania. – Turkish Journal of Zoology 37(1): 97–105. DOI: 10.3906/zoo-1203-25

Pavluvčík, P., Poprach, K., Machar, I., Losík, J., Gouveia, A. & Tkadlec, E. 2015. Barn Owl productivity response to variability of vole populations. – PloS One 10(12): e0145851. DOI: 10.1371/journal.pone.0145851

Paz, A., Jareño, D., Arroyo, L., Viñuela, J., Arroyo, B., Mougeot, F., Luque-Larena, J. J. & Fargallo, J. A. 2013. Avian predators as a biological control system of Common Vole *(Microtus arvalis)* populations in north-western Spain: experimental setup and preliminary results. – Pest Management Science 69(3): 444–450. DOI: 10.1002/ps.3289

Prete, S., Battisti, C., Marini, F. & Ciucci, P. 2012. Applying abundance/biomass comparisons on a small mammal assemblage from Barn Owl *(Tyto alba)* pellets (Mount Soratte, central Italy): a cautionary note. – Rendiconti Lincei 23(4): 349–354. DOI: 10.1007/s12210-012-0183-3

Purger, J. J. 1998. A Dráva mente Somogy megyei szakaszának kisemlős (Mammalia) faunája, gyöngybagoly, *Tyto alba* (Scopoli, 1769) köpetek vizsgálata alapján [Small mammal fauna of the region of Dráva river in country Somogy (Hungary), obtained by Bam Owl, *Tyto alba* (Scopoli, 1769) pellet analysis]. – Dunántúli Dolgozatok Természettudományi Sorozat 9: 489–500. (in Hungarian with English Summary)

R Development Core Team 2019. R: A Language and Environment for Statistical Computing. – https://www.r-project.org/.

Renwick, A. R. & Lambin, X. 2011. Abundance thresholds and the underlying ecological processes: Field Voles *Microtus agrestis* in a fragmented landscape. – Agriculture, Ecosystems & Environment 144(1): 364–369. DOI: 10.1016/j.agee.2011.10.006

Rocha, R. G., Ferreira, E., Leite, Y. L., Fonseca, C. & Costa, L. 2011. Small mammals in the diet of Barn Owls, *Tyto alba* (Aves: Strigiformes) along the mid-Araguaia River in central Brazil. – Zoologia (Curitiba) 28(6): 709–716. DOI: 10.1590/S1984-46702011000600003

Romano, A., Séchaud, R. & Roulin, A. 2020. Global biogeographical patterns in the diet of a cosmopolitan avian predator. – Journal of Biogeography 47(7): 1467–1481. DOI: 10.1111/jbi.13829

Roulin, A. 2015. Spatial variation in the decline of European birds as shown by the Barn Owl *Tyto alba* diet. – Bird Study 62(2): 271–275. DOI: 10.1080/00063657.2015.1012043

Sala, O. E., Chapin, F. S., Armesto, J. J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L. F., Jackson, R. B., Kinzig, A., Leemans, R., Lodge, D. M., Mooney, A. H., Oesterheld, M., Poff, N. L., Sykes, M. T., Walker, B. H., Walker, M. & Wall, D. H. 2000. Global biodiversity scenarios for the year 2100. – Science 287(5459): 1770–1774. DOI: 10.1126/science.287.5459.1770

Salvati, L., Ranazzi, L. & Manganaro, A. 2002. Habitat preferences, breeding success and diet of Barn Owls in Rome: urban versus rural territories. – Journal of Raptor Research 36: 224–228.

Schaefer, H. 1932. Die Artbestimmung der deutschen Anuren nach dem Skelet [Identification of the German anurans based on the skeleton]. – Zeitschrift für Anatomie und Entwicklungsgeschichte 97(6): 767–779. DOI: 10.1007/BF02121644 (in German)

Schmidt, E. 1967. Bagolyköpet vizsgálatok [Owl pellet analyses]. – Madártani Intézet, Budapest (in Hungarian)

Shawyer, C. R. & Shawyer, V. M. 1995. An investigation of the Barn Owl population within the Arun and Western Rother catchments. – Hawk and Owl Trust, London

Sokal, R. R. & Rohlf, F. J. 1995. Biomety: the Principles and Practice of Statistics in Biological Research. – New York, W. H. Freeman

Stoate, C., Báldi, A., Beja, P., Boatman, N. D. & Herzon, I. 2009. Ecological impacts of early 21st century agricultural change in Europe – a review. – Journal of Environmental Management 91(1): 22–46. DOI: 10.1016/j.jenvman.2009.07.005

Stoate, C., Boatman, N. D., Borralho, R. J., Carvalho, C. R., De Snoo, G. R. & Eden, P. 2001. Ecological impacts of arable intensification in Europe. – Journal of Environmental Management 63(4): 337–365. DOI: 10.1006/jema.2001.0473

Suchomel, J. & Heroldová, M. 2004. Small terrestrial mammals in two types of forest complexes in intensively managed landscape of South Moravia (The Czech Republic). – Ekologia (Bratislava) 23(4): 377–384.

Suchomel, J. & Purchart, L. 2011. Occurrence of *Crocidura leucodon* in plantings of forest trees in southern Moravia, Czech Republic (Soricomorpha: Soricidae). – Lynx 42: 271–274.

Szép, D., Klein, Á. & Purger, J. J. 2017. The prey composition of the Barn Owl with respect to landscape structure of its hunting area (Zala County, Hungary). – Ornis Hungarica 25(2): 51–64. DOI: 10.1515/orhu-2017-0015

Szép, D., Klein, Á. & Purger, J. J. 2019. Investigating the relationship between the prey composition of Barn Owls and the habitat structure of their hunting range in the Marcal Basin (Hungary), based on pellet analysis. – Ornis Hungarica 27(1): 32–43. DOI: 10.2478/orhu-2019-0002

Tattersall, F. H., Macdonald, D. W., Hart, B. J., Johnson, P., Manley, W. & Feber, R. 2002. Is habitat linearity important for small mammal communities on farmland? – Journal of Applied Ecology 39(4): 643–652. DOI: 10.1046/j.1365-2664.2002.00741.x

Taylor, I. 2004. Barn Owls: Predation-prey relationships and conservation. – Cambridge University Press, Cambridge

Teta, P., Hercolini, C. & Cueto, G. 2012. Variation in the diet of western Barn Owls *(Tyto alba)* along an urban-rural gradient. – The Wilson Journal of Ornithology 124: 589–596. 10.1676/11-173.1

Tews, J., Brose, U., Grimm, V., Tielbörger, K., Wichmann, M. C., Schwager, M. & Jeltsch F. 2004. Animal species diversity driven by habitat heterogeneity/diversity: the importance of keystone structures. – Journal of Biogeography 31(1): 79–92. DOI: 10.1046/j.0305-0270.2003.00994.x

Torre, I., Gracia-Quintas, L., Arrizabalaga, A., Baucells, J. & Díaz, M. 2015a Are recent changes in the terrestrial small mammal communities related to land use change? A test using pellet analyses. – Ecological Research 30(5): 813–819. DOI: 10.1007/s11284-015-1279-x

Torre, I., Fernández, L. & Arrizabalaga, A. 2015b Using Barn Owl *Tyto alba* pellet analyses to monitor the distribution patterns of the Yellow-necked Mouse (*Apodemus flavicollis* Melchior 1834) in a transitional Mediterranean mountain. – Mammal Study 40(3): 133–142. DOI: 10.3106/041.040.0302

Trejo, A. & Lambertucci, S. 2007. Feeding habits of Barn Owls along a vegetative gradient in northern Patagonia. – Journal of Raptor Research 41: 277–287. DOI: 10.3356/0892-1016(2007)41[277:FHOBOA]2.0.CO;2

Tulis, F., Baláž, M., Obuch, J. & Šotnár, K. 2015. Responses of the Long-eared Owl *Asio otus* diet and the numbers of wintering individuals to changing abundance of the Common Vole *Microtus arvalis*. – Biologia 70(5): 667–673. DOI: 10.1515/biolog-2015-0074

Venables, W. N. & Ripley, B. D. 2002. Modern Applied Statistics with S. – New York, Springer Publishing

Veselovský, T., Bacsa, K. & Tulis, F. 2017. Barn Owl *(Tyto alba)* diet composition on intensively used agricultural land in the Danube Lowland. – Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis 65(1): 225–233. DOI: 10.11118/actaun201765010225

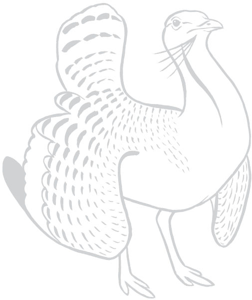
Wang, M. & Grimm, V. 2007. Home range dynamics and population regulation: an individual-based model of the Common Shrew *Sorex araneus*. – Ecological Modelling 205(3–4): 397–409. DOI: 10.1016/j.ecolmodel.2007.03.003

Yalden, D. W. 1977. Identification of Remains in Owl Pellets. – Mammal Society, London

Yalden, D. W. & Morris, P. A. 1990. The Analysis of Owl Pellets. – Mammal Society, London

Yletyinen, S. & Norrdahl, K. 2008. Habitat use of Field Voles *(Microtus agrestis)* in wide and narrow buffer zones. – Agriculture, Ecosystems & Environment 123(1–3): 194–200. DOI: 10.1016/j.agee.2007.06.002

Zebisch, M., Wechsung, F. & Kenneweg, H. 2004. Landscape response functions for biodiversity – assessing the impact of land-use changes at the county level. – Landscape and Urban Planning 67(1–4): 157–172. DOI: 10.1016/S0169-2046(03)00036-7



Ornis Hungarica 2023. 31(1): 111–125.
DOI: 10.2478/orhu-2023-0007

Diversity of cranial shape in European Woodpecker species (Picidae)

Tibor PECSICS[1,2*], Martin SEGESDI[3,4], Sándor FARAGÓ[1], Gerard GORMAN[5] & Tibor CSÖRGŐ[6]

Received: February 27, 2023 – Revised: May 15, 2023 – Accepted: May 16, 2023

Pecsics, T., Segesdi, M., Faragó, S., Gorman, G. & Csörgő, T. 2023. Diversity of cranial shape in European Woodpecker species (Picidae). – Ornis Hungarica 31(1): 111–125. DOI: 10.2478/orhu-2023-0007

Abstract The woodpecker family (Picidae) includes numerous species that vary in size and plumage colouration, but which share many easily recognisable external features. These birds possess pronounced anatomical adaptions that enable them to exploit arboreal habitats and live in niches that are inaccessible to most other birds. The aim of this study was to increase our knowledge on the relationships between skull shape, habitat preference, pecking abilities and foraging habits of 10 European woodpecker species. A geometric morphometric approach was used to analyse two-dimensional cranial landmarks. We used principal component (PC) analyses on those measurements that may be related to habitat preference and foraging habits. The PCs resulted in descriptions of the relative length and width of the bill, variation in its relative size, orientation of the nostrils variation in the elongation of the *neurocranium,* the relative size and position of the palatine bone, length of the *rostrum*, and the thickness of the mandible bone. The analysis showed and confirmed the presence of some cranial elements that are strongly associated with habitat preference, pecking behaviour and excavation abilities.

Keywords: woodpecker, skull shape, cranial morphology, morphometrics, anatomy, mandibles, kinetics, habitat preference

Összefoglalás A harkályok családja (Picidae) számos fajt tartalmaz, melyek többek között különböznek méretükben és tollazatuk mintázatában, azonban mindannyian rendelkeznek könnyen felismerhető közös külső jegyekkel. Ezek a madarak olyan szembeötlő tulajdonságokkal bírnak, amelyek lehetővé tették számukra olyan erdei élőhelyek és ökológiai fülkék meghódítását, amelyek más madarak számára elérhetetlenek. Tanulmányunkban az európai fajok *cranialis* jegyeinek elemzésével az élőhely-preferencia, a kopácsolási képességek és a morfológiai jellemzők közötti lehetséges összefüggéseket kerestük. A vizsgálat során kétdimenziós landmarkok használatával főkomponens analíziseket végeztünk. A főkomponensek a csőr relatív hosszát és szélességét, az orrnyílások relatív nagyságát és helyzetét, az agykoponya relatív nyújtottságát és annak görbületét, az arc- és agykoponya egymáshoz viszonyított méretét, a *palatinum* relatív nagyságát és helyzetét, valamint a *rostrum* relatív hosszát és a *mandibula* vastagságát, robuszticitását magyarázzák. A vizsgálat kimutatta, illetve megerősítette egyes koponyasajátosságok meglétét, amelyek az élőhely preferenciával, a táplálék megszerzésének módjával és a kopácsolási képességekkel szorosan összefüggnek.

Kulcsszavak: harkály, koponyasajátosságok, morfometria, anatómia, állkapocs, kinetika, élőhely-preferencia

[1] *University of Sopron, Institute of Wildlife Management and Wildlife Biology, 9400 Sopron, Bajcsy-Zsilinszky utca 4., Hungary*
[2] *Behavioural Ecology Group, Department of Systematic Zoology and Ecology, Eötvös Loránd University, 1117 Budapest, Pázmány Péter sétány 1/c, Hungary*
[3] *Department of Paleontology, Institute of Geography and Earth Sciences, Eötvös Loránd University, 1117 Budapest, Pázmány Péter sétány 1/c, Hungary*
[4] *Department of Paleontology and Geology, Hungarian Natural History Museum, 1431 Budapest, Pf. 137, Hungary*
[5] *Independent Researcher, Hungarian Woodpecker Working Group, c/o MME BirdLife Hungary, Budapest, Hungary*
[6] *Department of Anatomy, Cell- and Developmental Biology, Eötvös Loránd University, 1117 Budapest, Pázmány Péter sétány 1/c, Hungary*
** corresponding author, e-mail: nobilis.equus@gmail.com*

Introduction

Woodpeckers are the members of the avian family Picidae. They vary in size and plumage colouration, but generally share many easily recognisable external features. Woodpeckers have a global distribution, occurring from sea-level to high mountains on every continent except Madagascar, Australia-Oceania and Antarctica (Gorman 2014). These birds possess prominent anatomical adaptions that enable them to exploit arboreal habitats and live in niches that are inaccessible to most other birds (Cramp 1985). With the exception of a few species that live in treeless habitats, the Picidae are essentially arboreal, many being habitat specialists (Kerpez & Smith 1990). Some woodpecker species are closely associated with certain forest types and some with particular tree species (Moorea & Migliab 2009). Dead wood is also an important habitat requirement for many woodpecker species (Smith 2007, Nappi *et al.* 2015).

The family contains 230–250 species in 37 genera (Fuchs & Pons 2015, Shakya *et al.* 2017) but their taxonomy is complex and the exact relationships the axact relationships between species are still not calrified (Benz *et al.* 2006). In addition, the phylogenetic tree of the family is rather complicated due to hybridization between some species (Cracraft *et al.* 2004, Fuchs *et al.* 2013, Seneviratne *et al.* 2016).

Some recent studies suggest that woodpeckers have undergone convergent evolution and developed similar attributes independently (Moore *et al.* 2006, Dufort 2016).

The earliest picid ancestors probably evolved around 50 million years ago (Prum *et al.* 2015), although the fossil record is poor (James 2005, Kessler 2016) However, remains are known from the Late Oligocene (Mayr 2001) and Miocene epochs (De Pietri *et al.* 2011).

Numerous skull adaptations have evolved which facilitate excavation (reinforced *rhamphotheca*, frontal overhang, and *processus dorsalis pterygoidei*) and drumming and tapping (enlarged *condylus lateralis* of the quadrate and fused lower mandible) (Manegold & Töpfer 2013). These anatomical features function as shock-absorbers, preventing brain injuries and damage to the brain cavity. A curved maxilla and the presence of spongy tissue between the upper mandible and skull reduce pressure on the brain (Yoon & Park 2011, Liu *et al.* 2015). Micro-CT investigations have shown the presence of plate-like spongy bones and tissues in the skull, which are highly accumulated in the frontal and occipital regions (Wang *et al.* 2011).

A specially adapted hyoid bone allows these birds to retract and extend their tongue to extreme degrees (Yaraghi *et al.* 2016). When under tension, this structure also helps stabilize the skull and neck, and thus acts as a “seat belt” which also helps to prevent damage due to impacts occurring (Jung *et al.* 2019). The skull is thick and situated above the line of the bill, therefore the forces that occur while excavating, pecking and drumming are transmitted below the brain and the braincase through the mandibles. Furthermore, the quadrate bone and joints play important roles in extending impact time, which decreases impact load to the brain tissue (Xu *et al.* 2021).

The cranial bone has a high mineral density with plate-like structures and a high number of trabeculae packed together, which results in a lower deformation while pecking (Wang *et al.* 2013). The hearing apparatus has shock-proof adaptations and a thick membrane in the inner ear which further help in resisting damage (Kohllöffel 1984).

Another adaptation that mitigates damage is the relatively small size of the brain (Gibson 2006). However, although it is widely accepted that woodpecker skulls have special adaptations, some studies dispute the function of the cranial structures and suggest that these birds benefit from their overall small size and key skull features in order to safely hammer on and into wood to find invertebrates and to excavate nesting cavities (Biewener 2022).

Most woodpecker species are insectivorous but some are omnivorous and opportunistic. Their diet includes numerous species of arthropods, but also the eggs of other birds, nestlings, small vertebrates, fruits, nuts, seeds and other plant matter, tree sap and even carrion (Gregory *et al.* 2007, Gorman 2014).

Drumming is a form of non-vocal communication used by most (but not all) woodpecker species which has possibly played a key role in the development of cranial morphology and musculoskeletal attributes (Miles *et al.* 2018).

In this preliminary study, we investigated the cranial and morphological diversity among 10 European woodpecker species: Eurasian Wryneck *(Jynx torquilla)*, Lesser Spotted Woodpecker *(Dryobates minor)*, Middle Spotted Woodpecker *(Dendrocoptes medius)*, White-backed Woodpecker *(Dendrocopos leucotos)*, Great Spotted Woodpecker *(Dendrocopos major)*, Syrian Woodpecker *(Dendrocopos syriacus)*, Black Woodpecker *(Dryocopus martius)*, Eurasian Three-toed Woodpecker *(Picoides tridactylus)*, Eurasian Green Woodpecker *(Picus viridis)* and Grey-headed Woodpecker *(Picus canus)*. Our objective was to expand our knowledge on the relationship between skull shape and foraging habits and to identify any characteristics that are related to habitat preference and pecking and excavation abilities. The differences in the forces that act on the bill during pecking and excavation work may be related to skull geometry and jaw musculature. The differences between the various species may also reflect selection pressures related to their different foraging habits and habitat preferences (particularly concerning the hardness of wood). Furthermore, we aimed to re-examine the previous morphological observations that had involved both the most specialised and the least specialised species in terms of how they obtain food by pecking into trees (Bock 1999, Tarbill *et al.* 2015). To investigate the morphological diversity of the skulls of the ten species, we used landmark-based morphometric methods.

Materials and Methods

Specimens

This study is based on 70 skulls from 10 European species. All skulls are from adult specimens of woodpeckers in the collection of the Eötvös Loránd University (Budapest, Hungary, n=21), the collection of the Hungarian Natural History Museum (Budapest, Hungary, n=31), the digital archives of Wageningen University (Wageningen, Netherlands, n=5), the Museum of Natural Sciences of Barcelona (Barcelona, Spain, n=2) and the Natural History Museum of Krakow (Krakow, Poland, n=11). No birds were deliberately killed in order to obtain their skull; all either died of natural causes, accidentally or whilst in captivity.

Table 1. List of woodpecker species examined in this study
1. táblázat A vizsgálatban szereplő harkályfajok

Common name	**Scientific name**	**n**
Eurasian Wryneck	*Jynx torquilla*	7
Lesser Spotted Woodpecker	*Dryobates minor*	2
Middle Spotted Woodpecker	*Dendrocoptes medius*	5
White-backed Woodpecker	*Dendrocopos leucotos*	8
Great Spotted Woodpecker	*Dendrocopos major*	17
Syrian Woodpecker	*Dendrocopos syriacus*	8
Black Woodpecker	*Dryocopus martius*	4
Eurasian Three-toed Woodpecker	*Picoides tridactylus*	5
Eurasian Green Woodpecker	*Picus viridis*	10
Grey-headed Woodpecker	*Picus canus*	4

Landmarks and procedures

The variation of cranial morphology was analysed using landmark-based geometric morphometry. In this study, the meaningful variables were revealed by the analysis. We sought to find landmarks for this analysis to cover the geometric form of the skull. The landmarks enabled a comprehensive sampling of morphology and thus features of biological significance could be explored. The ideal landmarks were discrete but noticeable anatomical features, which did not alter their topological positions relative to other landmarks and provided adequate coverage of the morphology (Zelditch *et al.* 2004). The landmarks were obtained

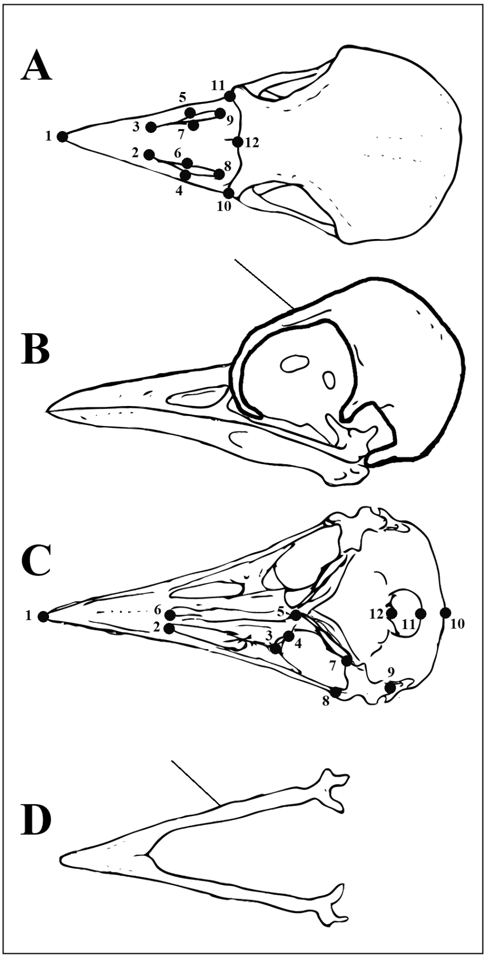


Figure 1. Position and number of landmarks. A: the bill in dorsal view (numbers correspond to *Table 2*), B: the *neurocranium* in lateral view, C: fixed landmarks in ventral view (numbers correspond to *Table 3*), D: the mandible in ventral view

1. ábra A vizsgálatban használt landmarkok száma és pozíciója. A: a csőr felülnézetből (a számok megnevezését lásd a *2. táblázatban*), B: az agykoponya oldalnézetből, C: fix landmarkok alulnézetből (a számok megnevezését lásd a *3. táblázatban*), D: az alsó állkapocs alulnézetből

Table 2. Number and description of landmarks. Terminology according to (Baumel 1993)
2. táblázat Az egyes landmarkok száma és leírása. Terminológia Baumel (1993) alapján

Number of landmark	Description of landmark
1	tip of the *maxilla*
2	the most anterior point of the left nostril
3	the most anterior point of the right nostril
4	the most lateral point of the left nostril
5	the most lateral point of the right nostril
6	the most medial point of the left nostril
7	the most medial point of the right nostril
8	the most posterior point of the left nostril
9	the most posterior point of the right nostril
10	the most posterior point of the left *maxilla*
11	the most posterior point of the right *maxilla*
12	the middle of the nasofrontal hinge

Table 3. Number and description of landmarks. Terminology according to (Baumel 1993, Sun *et al.* 2018)
3. táblázat Az egyes landmarkok száma és leírása. Terminológia Baumel (1993) és Sun *et al.* (2018) alapján

Number of landmark	Description of landmark
1	tip of the *maxilla*
2	the lateral associating point of palatine and *maxilla*
3	the most anterior-lateral point of *pars lateralis*
4	the most posterior-lateral point of *pars lateralis*
5	*processus pterygoideus* of palatine
6	articulation point of palatine and *maxilla*
7	articulation point of pterygoid and quadrate
8	articulation of quadrate and jugal
9	most lateral point of *opisthotic*
10	prominentia cerebellaris
11	most caudal point of *foramen magnum*
12	most caudal point of *condylus occipitalis*

via high resolution (1200 × 1600 pixels) photographs. We took four photographs of each specimen (lateral, ventral, and dorsal) with closed jaws and without the mandibles. Images were standardised for the *foramen magnum occipitale* and the tip of the bill. Those specimens which lacked the *ramphotheca* but on which the tip of the bill was identifiable, were measured. An investigation was performed regarding the repeatability of the measurements by using Spearman's correlation. The test was between two separate digital measurements performed on skull photos (n=20). We used 12 fixed landmarks in dorsal and ventral views to examine the shape of the bill and 500 sliding landmarks to examine the shape of the *neurocranium* in lateral view and a further 200 sliding landmarks to examine the shape of the mandible *(Figure 1)*. These landmarks were allowed to slide along their corresponding curves due to the minimisation of the pliable energy. The coordinates of the landmarks were digitised using TpsDig 2.16 software (Rohlf 2010) and were transformed using the Procrustes superimposition method. Consensus configurations and relative warps were conducted. Variability in shape was assessed using the scores obtained for each individual on the first two relative warps. We conducted principal component analyses (PCA) on these morphological variables. The relative warps correspond to the principal components (PCs) and define the shape space in which individuals are replaced. We used PAST v.1.7 software (Hammer *et al.* 2001) to perform principal component analysis and extract deformation grids. We only considered those PCs which showed >10% of variance.

Results

Our measurements were meaningful, irrespective of the measuring mode (all r > 0.98, all P < 0.001).

The first analysis tried to describe the shape of the bill with fixed landmarks (12) in dorsal view. The first two PCs showed 64% and 14% of variance in shape. The first PC axis

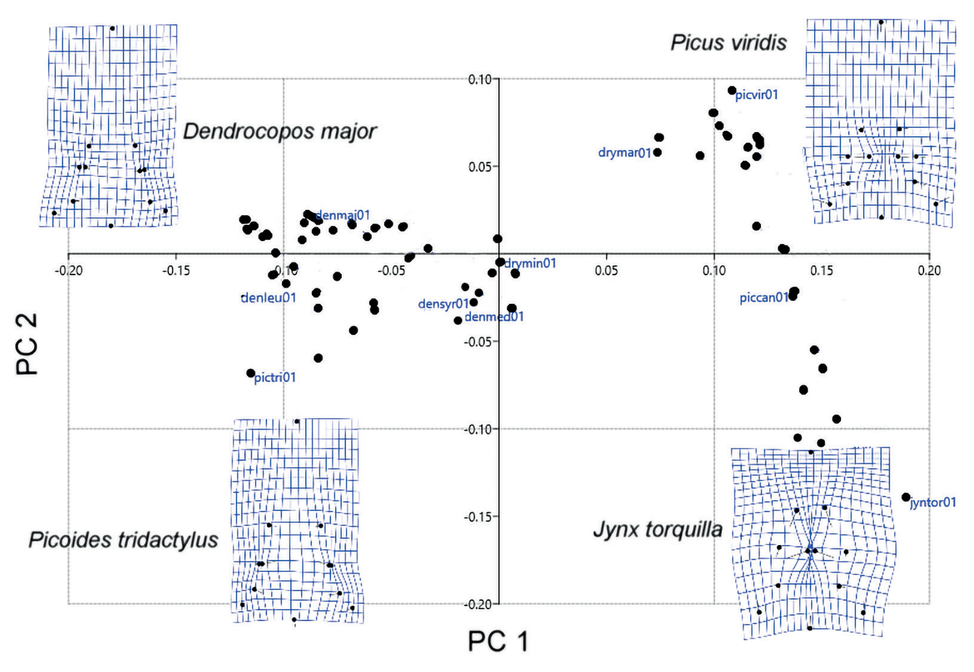


Figure 2. Graphical output of first PCA performed on the two-dimensional landmark data (dorsal view). PC1–PC2 biplot

2. ábra Az első PCA grafikus megjelenítése kétdimenziós landmark adatok alapján (felülnézet)

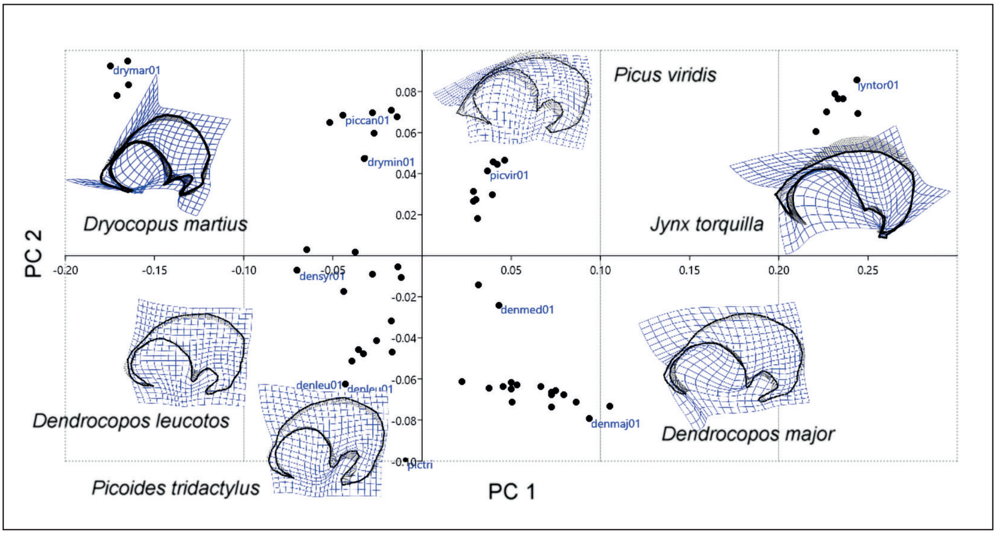


Figure 3. Graphical output of second PCA performed on the two-dimensional landmark data (lateral view). PC1–PC2 biplot

3. ábra A második PCA grafikus megjelenítése kétdimenziós landmark adatok alapján (oldalnézet)

described variation in the relative length and width of the bill (PC1) and the second reflected to the relative size of the nostril and its distance from the tip of the bill (PC2). The analysis showed that the Eurasian Wryneck differs considerably from its relatives *(Figure 2)*.

The second analysis focused on the *neurocranium* and the orbits from the lateral view *(Figure 1)*. We used sliding landmarks (500) to describe the cranial shape of each

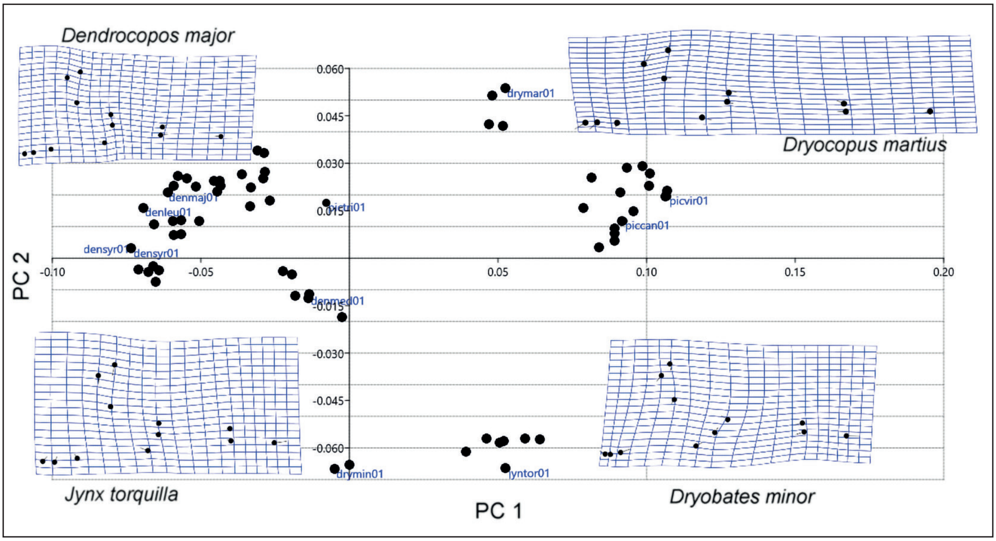


Figure 4. Graphical output of third PCA performed on the two-dimensional landmark data (ventral view). PC1–PC2 biplot

4. ábra A harmadik PCA grafikus megjelenítése kétdimenziós landmark adatok alapján (alulnézet)

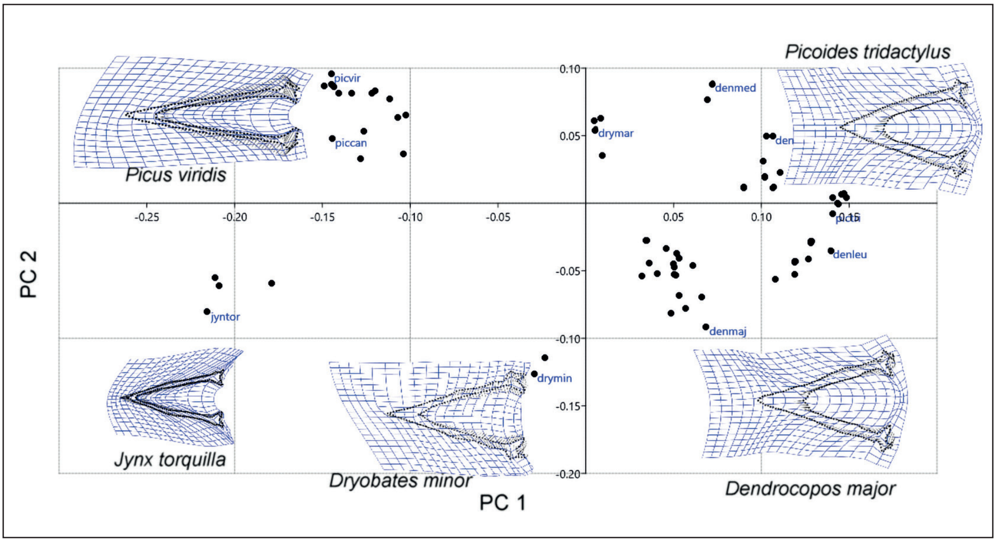


Figure 5. Graphical output of fourth PCA performed on the two-dimensional landmark data (ventral view). PC1–PC2 biplot

5. ábra A negyedik PCA grafikus megjelenítése kétdimenziós landmark adatok alapján (alulnézet)

woodpecker. The first three PCs showed 52%, 22% and 12% of variance in skull shape. The first PC axis described the relative length and elongation of the *neurocranium* (PC1). The Eurasian Wryneck, European Green Woodpecker and Grey-headed Woodpecker also showed differences, with relatively low and narrow *neurocranium* compared to other species with short skulls. The second PC axis described the relative height and curvature of the *neurocranium* (PC2). Species like Eurasian Three-toed Woodpecker and White-backed Woodpecker share similar morphology *(Figure 3)*. The third PC axis (PC3) showed the position and thickness of *processus postorbitalis* and *processus paroccipitalis*. The species that are more adapted for excavating into and pecking on wood showed more scores and bearing wider and stronger bony processes *(Figure 3)*.

During the third analysis we used fixed landmarks (12) in dorsal view *(Figure 1)*. The first two PCs showed 48% and 14% of the variance in shape. The first PC axis described variation in the relative size of the *neurocranium* compared to the *viscerocranium* (PC1) and the second reflected to the relative size of the palatine bone and its distance from the tip of the bill (PC2). The analysis showed that more primitive forms are different from those species that have more evolved attributes for pecking and excavating *(Figure 4)*.

The fourth analysis focused on the mandible bone in ventral view *(Figure 1)*. We used 200 sliding landmarks to find the main differences between the species. The first two PCs showed 65% and 24% of variance in shape. The first PC axis related to the variation of the relative thickness and length of the *rostrum* (PC1). The second PC axis described the relative thickness of mandible bone (PC2) *(Figure 5)*.

In every case, the generalist species are situated the middle of the morphospace. The less evolved species with more ancient attributes differ prominently from those woodpeckers that share more adaptations for working on harder wood surfaces *(Figure 7)*.

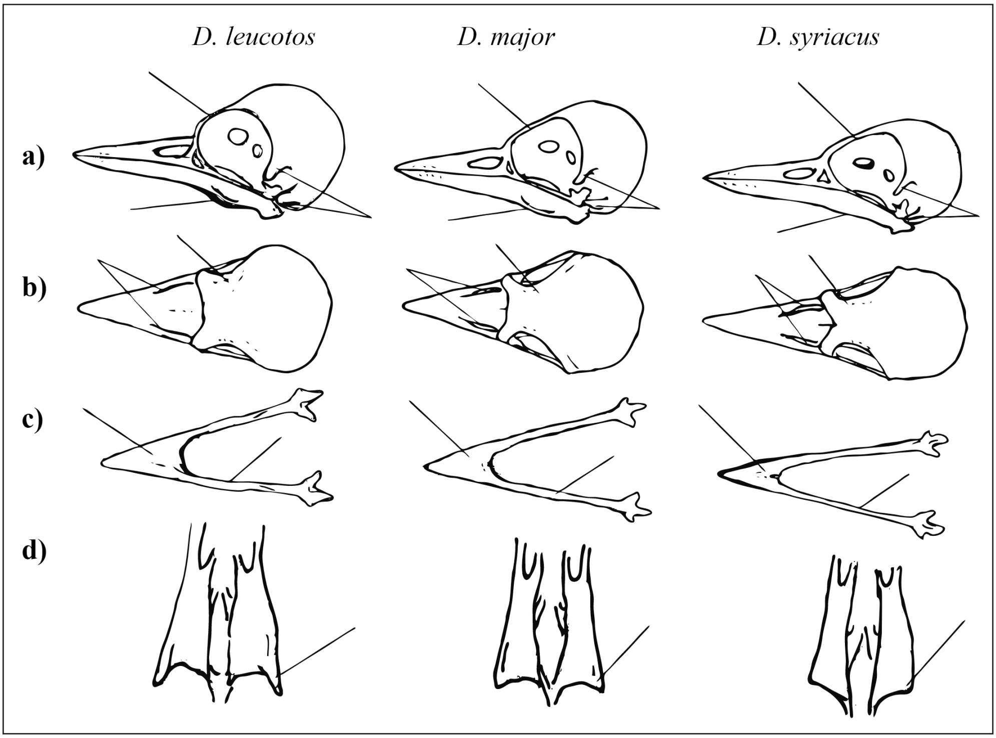


Figure 6. Various *Dendrocopos* species differ in some skull attributes that are related to the preferred wood materials and the mass of jaw closure muscles: a) skull in lateral view, b) skull in dorsal view, c) mandible in ventral view, d) palatine bone in ventral view

6. ábra Egyes *Dendrocopos* fajok különböznek azokban a koponyatulajdonságaikban, amelyek a preferált faanyaggal és az állkapcsot záró izomzat tömegével vannak összefüggésben: a) koponya oldalnézetben, b) koponya felülnézetben, c) a *mandibula* alulnézetben, d) a *palatinum* alulnézetben

Discussion

We found that in dorsal view there are differences in the shape of the relative length and width of the bill and the relative size and position of the nostrils. Larger species like Black Woodpecker and European Green Woodpecker, have longer bills compared to the *neurocranium*. The allometric head growth could reflect variation in head length. It might also explain some of the differences between species because birds with a smaller body size usually have a bigger *neurocranium* and a smaller *viscerocranium* as in the case of the Lesser Spotted Woodpecker. Allometric patterns within populations do not necessarily parallel interspecific allometry (Grant *et al.* 1985). Despite the comparable size of Great Spotted Woodpecker and Middle Spotted Woodpecker, the ratio between *neurocranium* and *viscerocranoum* are different. The Middle Spotted Woodpecker has a shorter bill and relatively elongated skull which corresponds to its behaviour as a mostly foraging species that works on surfaces and does not bore deeply into wood (Pettersson 1983, Török 1990,

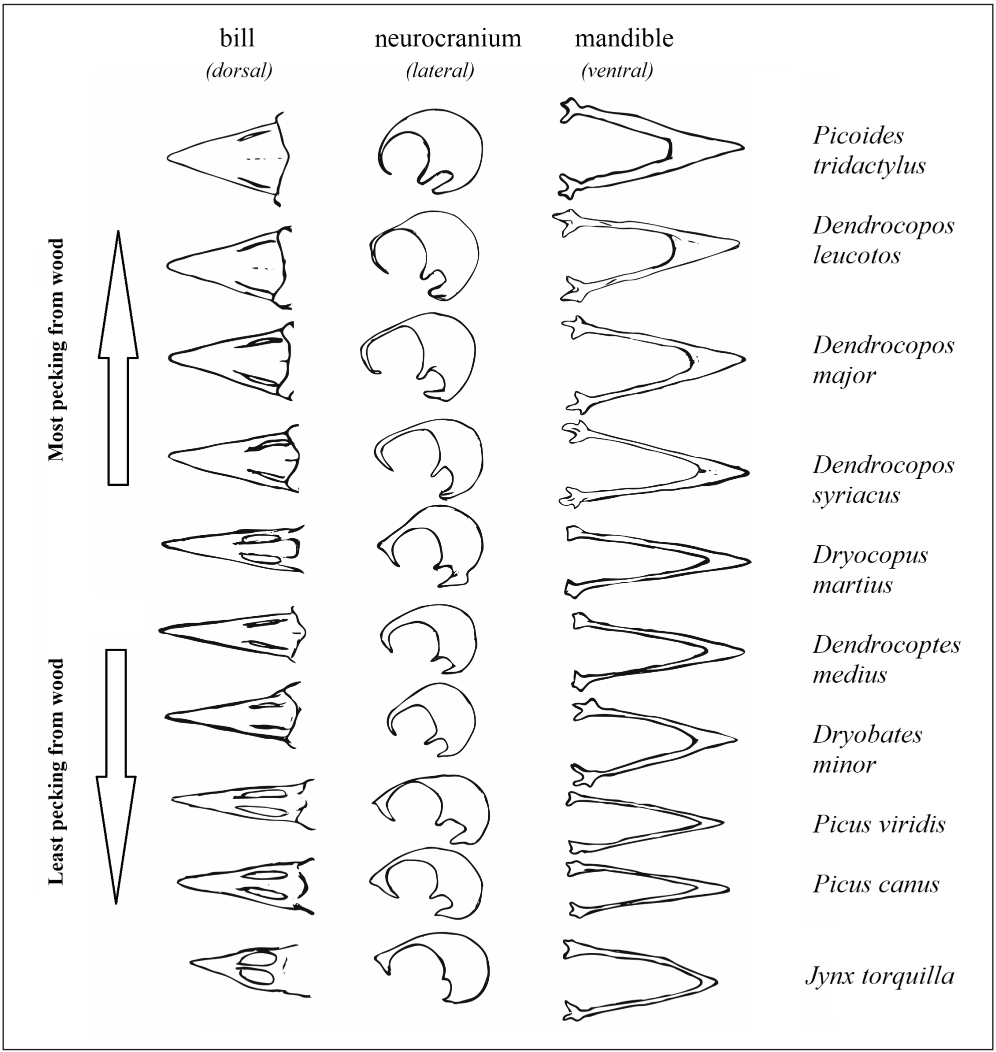


Figure 7. Differences in cranial morphology between species in case of pecking and excavation abilities

7. ábra A koponyamorfológiában megmutatkozó különbségek az egyes fajok között a táplálék megszerzését és a fakopácsolási képességeket illetően

Gorman 2014, 2020). The most primitive form of European woodpeckers is the Eurasian Wryneck in that it does not possess progressive adaptations for extracting food items from under the surface of trees. However, despite the lack of specialisation of skull attributes, Wrynecks still perform some basic drumming (Turner & Gorman 2021). It is possible that these nest-related activities could have led the ancestors of modern picids to those complex movements and behaviours that enable them to obtain their food from difficult to reach places within wood (Short 1971, Bock 1999). Species that forage on the surface or collect their food from dead wood, have mostly elongated bills and their nostrils are closer to each other. Their skulls cannot resist the mechanical stresses and demands that those of the more evolved and advanced species can, such as the European Three-toed Woodpecker (Lee *et al.* 2016, Moody *et al.* 2022). The more adapted species that mostly peck into wood have a wider base on their upper mandible and a larger space between the nostrils. The width and shape of the flexible region between the *nasale* and the *frontale* determines the mechanical stability of the structure, and the nostrils follow passively the edge of the flexible region, therefore the nostrils are getting into an increasingly "marginal" position (Jung *et al.* 2019).

The second analysis showed clear differences between those species that peck least and those that peck most. Wryneck, Green Woodpecker and Grey-headed Woodpecker have elongated *neurocranium* with a lower forehead. The species that peck more, have a higher forehead, the curvature of their frontal bone is more pronounced and prominent and the shape of the *neurocranium* is also rounder. These attributes are undisputed adaptations for obtaining food from within hard wood and to help resist the shocks sustained during pecking and excavating (Young *et al.* 2019). Between the closely related *Dendrocopos* species we can observe a gradient regarding these cranial attributes which corresponds their tree and habitat preferences (Ónodi & Csörgő 2012, 2013, 2014) *(Figure 6)*. With the exception of the Wryneck, those species that possess an elongated skull mostly have a longer bill as well. The Black Woodpecker is also an exception to this rule because of its size and habitat preferences (Rolstad & Rolstad 1995, Rolstad *et al.* 1998, Bocca *et al.* 2007). Black Woodpecker is highly insectivorous, its diet mainly includes ants (especially carpenter ants) and wood-boring beetles. The densities of these prey species are higher in forests rich in mature and dead wood. Their long bill enables them to reach prey, especially larvae, which are found deep within trees (Mikusinski 1995, Garmendia *et al.* 2006). The orbits of advanced pecking species are located more frontally and the lacrimal bones are completely covered at the front to help resist shocks from impacts and protect the sensitive eyes from forces of inertia. The position and thickness of cranial processes, like *processus postorbitalis* and *processus paroccipitalis,* are positively loaded with the mass and strength of mandible closing muscles (Donatelli 2012).

The third analysis showed differences in the relative length of the *viscerocranium* but also the mandible closing muscles. Those species with a larger surface of palatine bones also possess more mandible closing muscles in order to maximize their forces. These factors were relatively underestimated in previous studies on this subject, however, mandible closing muscles play an essential role when these birds are drumming, pecking and excavating. The palatine bones with pterygoids play a key role during cranial kinesis as they increase the shock-absorbing ability of the bony structures of the cranium (Spring 1965, Jung *et al.* 2019).

The fourth analysis described variation of the relative length of the *rostrum* and the relative thickness of the mandible bone. A clear gradient was evident from those species that peck and excavate less, to those that do so more. The mandible bone has a key role during excavating and pecking (Spring 1965, Wang *et al.* 2013). The relative length of the *rostrum* and the relative thickness of the mandible bone both increase in the more evolved species as an adaptive response to mechanical demands. The characteristics of the mandible bone are suitable as a means to identify the different species (Kessler 2016). The habitat preferences of each woodpecker species corresponds with their cranial attributes, because these species are mostly non-migratory (Pasinelli 2006) and their home ranges are linked to certain trees and forests (Michalczuk *et al.* 2018, Vadász *et al.* 2022). Climatic changes and changes in flora elements through glacial and interglacial periods most likely had major effects on closely related species (like the *Dendrocopos*) and worked as a significant factor during speciation (Varga 2009, Horsák *et al.* 2015, Szatmári 2015, Shakya *et al.* 2017). It is also possible that some unique attributes may have evolved in isolated populations.

Our results show relationships between cranial attributes and habitat preferences, and furthermore, they highlight the complexity and diversity of foraging behaviours. Future studies reflecting on avian cranial apparatus may well increase our knowledge and may be useful in understanding the preferences of different woodpecker species. With a larger sample size, a future investigation could possibly highlight differences between the sexes and elucidate a more complex picture of the behaviour of these birds. The diversity in appearance of those cranial elements that are essential in special movements and adaptations of shock absorbing, may help our understanding of how modern picids evolved from primitive ones. Collecting skull samples of species from different regions of the continent might reveal differences in subspecies and provide a detailed view of the possible polarisation of morphological patterns and niche segregation. More specified future studies might reveal more morphological characteristics that possess informative attributes (e.g. the musculoskeletal structures of the neck) (Péczely 1963). In this study, we did not investigate the effect of phylogeny, but a phylogenetic control would be advisable in any subsequent analysis.

Acknowledgements

We are grateful to Gabriella Bóka and Jenő Nagy for their comments. We also thank Péter Urtz and Mihály Gasparik for their technical assistance. Special thanks to Krysztof Wertz and Hailey Veinot.

References

Baumel, J. J. 1993. Handbook of avian anatomy: Nomina Anatomica Avium. – Publications of the Nuttall Ornithological Club (USA), no. 23.

Benz, B. W., Robbins, M. B. & Peterson, A. T. 2006. Evolutionary history of woodpeckers and allies (Aves: Picidae): placing key taxa on the phylogenetic tree. – Molecular Phylogenetics and Evolution 40(2): 389–399. DOI: 10.1016/j.ympev.2006.02.021

Biewener, A. A. 2022. Physiology: Woodpecker skulls are not shock absorbers. – Current Biology 32(14): 767–769. DOI: 10.1016/j.cub.2022.06.037

Bocca, M., Carisio, L. & Rolando, A. 2007. Habitat use, home ranges and census techniques in the Black Woodpecker *Dryocopus martius* in the Alps. – Ardea 95(1): 17–29. DOI: 10.5253/078.095.0103

Bock, W. J. 1999. Functional and evolutionary morphology of woodpeckers. – Ostrich 70(1): 23–31. DOI: 10.1080/00306525.1999.9639746

Cracraft, J., Barker, F. K., Braun, M. J., Harshman, J., Dyke, G. J., Feinstein, J., Stanley, S., Cibois, A., Schikler, P., Beresford, P., García-Moreno, J., Sorenson, M. D., Yuri, T. & Mindell, D. P. 2004. Phylogenetic relationships among modern birds (Neornithes). – In: Cracraft, J., Donoghue, M. J. & Donoghue, M. M. (eds.) Assembling the Tree of Life. – New York Oxford University Press, pp. 468–489.

Cramp, S. 1985. Handbook of the Birds of Europe, the Middle East, and North Africa: The birds of the Western Palearctic, Vol. 4. Terns to Woodpeckers. – Oxford University Press

De Pietri, V. L., Manegold, A., Costeur, L. & Mayr, G. 2011. A new species of Woodpecker (Aves; Picidae) from the early Miocene of Saulcet (Allier, France). – Swiss Journal of Palaeontology 130(2): 307–314. DOI: 10.1007/s13358-011-0021-8

Donatelli, R. J. 2012. Jaw musculature of the Picini (Aves: Piciformes: Picidae). – International Journal of Zoology Article ID 941678. DOI: 10.1155/2012/941678

Dufort, M. J. 2016. An augmented supermatrix phylogeny of the avian family Picidae reveals uncertainty deep in the family tree. – Molecular Phylogenetics and Evolution 94(1): 313–326. DOI: 10.1016/j.ympev.2015.08.025

Fuchs, J., Pons, J. M., Liu, L., Ericson, P. G., Couloux, A. & Pasquet, E. 2013. A multi-locus phylogeny suggests an ancient hybridization event between *Campephilus* and melanerpine woodpeckers (Aves: Picidae). – Molecular Phylogenetics and Evolution 67(3): 578–588. DOI: 10.1016/j.ympev.2013.02.014

Fuchs, J. & Pons, J. M. 2015. A new classification of the Pied Woodpeckers assemblage (Dendropicini, Picidae) based on a comprehensive multi-locus phylogeny. – Molecular Phylogenetics and Evolution, 88(7): 28–37. DOI: 10.1016/j.ympev.2015.03.016

Garmendia, A., Cárcamo, S. & Schwendtner, O. 2006. Forest management considerations for conservation of Black Woodpecker *Dryocopus martius* and White-backed Woodpecker *Dendrocopos leucotos* populations in Quinto Real (Spanish Western Pyrenees). – In: Hawksworth, D. L. & Bull, A. T. (eds.) Forest Diversity and Management. Topics in Biodiversity and Conservation, Vol. 2. Springer DOI: 10.1007/978-1-4020-5208-8_18

Gibson, L. J. 2006. Woodpecker pecking: how Woodpeckers avoid brain injury. – Journal of Zoology 270(3): 462–465. DOI: 10.1111/j.1469-7998.2006.00166.x

Gorman, G. 2014. Woodpeckers of the World: The Complete Guide. – Bloomsbury

Gorman, G. 2020. Attributes of Eurasian Green Woodpecker *(Picus viridis)* nest cavities in Hungary. – Ornis Hungarica 28(2): 204–211. DOI: 10.2478/orhu-2020-0025

Grant, P. R., Abbott, I., Schluter, D., Curry, R. L. & Abbott, L. K. 1985. Variation in the size and shape of Darwin's finches. – Biological Journal of the Linnean Society 25(1): 1–39. DOI: 10.1111/j.1095-8312.1985.tb00384.x

Gregory, R. D., Vorisek, P., Van Strien, A., Gmeling Meyling, A. W., Jiguet, F., Fornasari, L., Reif, J., Chylarecki, P. & Burfield, I. J. 2007. Population trends of widespread woodland birds in Europe. – Ibis 149(Suppl.2): 78–97. DOI: 10.1111/j.1474-919X.2007.00698.x

Hammer, Ø., Harper, D. A. T. & Ryan, P. D. 2001. PAST: paleontological statistics software package for education and data analysis. – Palaeontologia Electronica 4: 1–9.

Horsák, M., Chytrý, M., Hájková, P., Hájek, M., Danihelka, J., Horsáková, V., Ermakov, N., German, D. A., Kočí, M., Lustyk, P. & Nekola, J. C. 2015. European glacial relict snails and plants: environmental context of their modern refugial occurrence in southern Siberia. – Boreas 44(4): 638–657. DOI: 10.1111/bor.12133

James, H. F. 2005. Paleogene fossils and the radiation of modern birds. – The Auk 122(4): 1049–1054. DOI: 10.1642/0004-8038(2005)122[1049:Pfatro]2.0.Co;2

Jung, J. Y., Pissarenko, A., Trikanad, A. A., Restrepo, D., Su, F. Y., Marquez, A., Gonzalez, D., Naleway, S. E., Zavattieri, P. & McKittrick, J. 2019. A natural stress deflector on the head? Mechanical and functional evaluation of the woodpecker skull bones. – Advanced Theory and Simulations 2(4): 1800152. DOI: 10.1002/adts.201800152

Kerpez, T. A. & Smith, N. S. 1990. Competition between European Starlings and native woodpeckers for nest cavities in saguaros. – The Auk 107(2): 367–375. DOI: 10.2307/4087621

Kessler, J. E. 2016. Picidae in the European fossil, subfossil and recent bird faunas and their osteological characteristics. – Ornis Hungarica 24(1): 96–114. DOI: 10.1515/orhu-2016-0006

Kohllöffel, L. U. E. 1984. Notes on the comparative mechanics of hearing. I. A shock-proof ear. – Hearing Research 13(1): 73–76. DOI: 10.1016/0378-5955(84)90096-0

Lee, N., Horstemeyer, M. F., Prabhu, R., Liao, J., Rhee, H., Hammi, Y., Moser, R. D. & Williams, L. N. 2016. The geometric effects of a woodpecker's hyoid apparatus for stress wave mitigation. – Bioinspiration & Biomimetics 11(6): 066004. DOI: 10.1088/1748-3190/11/6/066004

Liu, Y., Qiu, X., Zhang, X. & Yu, T. X. 2015. Response of woodpecker's head during pecking process simulated by material point method. – PloSOne 10(40): 1–16. DOI: 10.1371/journal.pone.0122677

Manegold, A. & Töpfer, T. 2013. The systematic position of *Hemicircus* and the stepwise evolution of adaptations for drilling, tapping and climbing up in true woodpeckers (Picinae, Picidae). – Journal of Zoological Systematics and Evolutionary Research 51(1): 72–82. DOI: 10.1111/jzs.12000

Mayr, G. 2001. The earliest fossil record of a modern-type piciform bird from the late Oligocene of Germany. – Journal für Ornithologie 142(1): 2–6. DOI: 10.1046/j.1439-0361.2000.00048.x

Michalczuk, J., Boruchalski, D., Mazurek, P., Mazurek, M., Michalczuk, M. & Cymbała, R. 2018. Woodpeckers Picidae in the agricultural landscape of the eastern part of Zamość Region. – Ornis Polonica 59(4): 231–249.

Mikusiński, G. 1995. Population trends in Black Woodpecker in relation to changes and characteristics of European forests. – Ecography 18(4): 363–369. DOI: 10.1111/j.1600-0587.1995.tb00139.x

Miles, M. C., Schuppe, E. R., Ligon, IV., R. M. & Fuxjager, M. J. 2018. Macroevolutionary patterning of Woodpecker drums reveals how sexual selection elaborates signals under constraint. – Proceedings of the Royal Society B: Biological Sciences 285(1): 1–9. DOI: 10.1098/rspb.2017.2628

Moody, N. M., Vivlamore, E. K. & Fuxjager, M. J. 2022. Woodpecker drum evolution: An analysis of covariation in elements of a multicomponent acoustic display among and within species. – Evolution 76(7): 1469–1480. DOI: 10.1111/evo.14535

Moore, W. S., Weibel, A. C. & Agius, A. 2006. Mitochondrial DNA phylogeny of the Woodpecker genus *Veniliornis* (Picidae, Picinae) and related genera implies convergent evolution of plumage patterns. – Biological Journal of the Linnean Society 87(4): 611–624. DOI: 10.1111/J.1095-8312.2006.00586.X

Moorea, W. S. & Migliab, K. J. 2009. Woodpeckers, Toucans, and allies (Piciformes). – In: Hedges, S. B. & Kumar, S. (eds.) The Timetree of Life. – Oxford University Press, pp. 445–450.

Nappi, A., Drapeau, P. & Leduc, A. 2015. How important is dead wood for woodpeckers foraging in eastern North American boreal forests? – Forest Ecology and Management 346: 10–21. DOI: 10.1016/j.foreco.2015.02.028

Ónodi, G. & Csörgő, T. 2012. The habitat preference of the Great Spotted Woodpecker (*Dendrocopos major* Linnaeus, 1758). – 3rd European Congress of Conservation Biology, Glasgow, poster 46.

Ónodi, G. & Csörgő, T. 2013. Relationship between vegetation structure and abundance of Great-spotted Woodpeckers *(Dendrocopos major)* in a mosaic habitat. – Ornis Hungarica 21(1): 1–11. DOI: 10.2478/orhu-2013-0011

Ónodi, G. & Csörgő, T. 2014. Habitat preference of Great-spotted Woodpecker (*Dendrocopos major* Linnaeus, 1758) and Lesser-spotted Woodpecker (*Dendrocopos minor Linnaeus*, 1758) in the presence of invasive plant species preliminary study. – Ornis Hungarica 22(2): 50–64. DOI: 10.2478/orhu-2014-0018

Pasinelli, G. 2006. Population biology of European woodpecker species: a review. – Annales Zoologici Fennici 43(2): 96–111.

Pettersson, B. 1983. Foraging behaviour of the Middle Spotted Woodpecker *Dendrocopos medius* in Sweden. – Ecography 6(3): 263–269. DOI: 10.1111/j.1600-0587.1983.tb01090.x

Péczely, P. 1963. A madarak kopácsoló mozgásának hatása a nyakcsigolyák alakulására [The influence of the excavation movement of birds on the development of the cervical vertebrae]. – Aquila 69–70: 131–144. (in Hungarian)

Prum, R. O., Berv, J. S., Dornburg, A., Field, D. J., Townsend, J. P., Lemmon, E. M. & Lemmon, A. R. 2015. A comprehensive phylogeny of birds (Aves) using targeted next-generation DNA sequencing. – Nature 526(7574): 569–573. DOI: 10.1038/nature15697

Rohlf, F. J. 2010. TpsDig, version 2.16. – Department of Ecology and Evolution, State University of New York, Stony Brook, USA

Rolstad, J. & Rolstad, E. 1995. Seasonal patterns in home range and habitat use of the Grey-headed Woodpecker *Picus canus* as influenced by the availability of food. – Ornis Fennica 72(1): 1–13.

Rolstad, J., Majewski, P. & Rolstad, E. 1998. Black Woodpecker use of habitats and feeding substrates in a managed Scandinavian forest. – The Journal of Wildlife Management 62(1): 11–23. DOI: 10.2307/3802260

Seneviratne, S. S., Davidson, P., Martin, K. & Irwin, D. E. 2016. Low levels of hybridization across two contact zones among three species of woodpeckers *(Sphyrapicus sapsuckers)*. – Journal of Avian Biology 47(6): 887–898. DOI: 10.1111/jav.00946

Shakya, S. B., Fuchs, J., Pons, J. M. & Sheldon, F. H. 2017. Tapping the woodpecker tree for evolutionary insight. – Molecular Phylogenetics and Evolution 116(1): 182–191. DOI: 10.1016/j.ympev.2017.09.005

Short, L. L. 1971. The evolution of terrestrial woodpeckers. – American Museum Novitates; no. 2467.

Smith, K. W. 2007. The utilization of dead wood resources by woodpeckers in Britain. – Ibis 149(2): 183–192. DOI: 10.1111/j.1474-919X.2007.00738.x

Spring, L. W. 1965. Climbing and pecking adaptations in some North American woodpeckers. – The Condor 67(6): 457–488. DOI: 10.2307/1365612

Szatmári, P-M. 2015. Additional Glacial Relicts in Carei Plain natural protected area, north-western Romania. – Acta Horti Botanica Bucurest 42(1): 23–40. DOI: 10.1515/ahbb-2015-0003

Tarbill, G. L., Manley, P. N. & White, A. M. 2015. Drill, baby, drill: The influence of woodpeckers on post-fire vertebrate communities through cavity excavation. – Journal of Zoology 296(2): 95–103. DOI: 10.1111/jzo.12220

Török, J. 1990. Resource partitioning among three woodpecker species *Dendrocopos* spp. during the breeding season. – Ecography 13(4): 257–264. DOI: 10.1111/j.1600-0587.1990.tb00617.x

Turner, K. & Gorman, G. 2021. The instrumental signals of the Eurasian Wryneck. – Ornis Hungarica 29(1): 98–107. DOI: 10.2478/orhu-2021-0007

Vadász, Cs., Kocsán, G. & Ónodi, G. 2022. Testing different isolation distances in woodpecker territory mapping in Central Hungary. – Ornis Hungarica 30(2): 1–9. DOI: 10.2478/orhu-2022-0016

Varga, Z. 2009. Extra-Mediterranean refugia, post-glacial vegetation history and area dynamics in Eastern Central Europe. – In: Habel, J. & Assmann, T. (eds.) Relict species: phylogeography and conservation biology. – Springer Berlin, Heidelberg DOI: 10.1007/978-3-540-92160-8_3

Wang, L., Cheung, J. T. M., Pu, F., Li, D., Zhang, M. & Fan, Y. 2011. Why do woodpeckers resist head impact injury: a biomechanical investigation. – PloS One 6(10): 1–8. DOI: 10.1371/journal.pone.0026490

Wang, L., Lu, S., Liu, X., Niu, X., Wang, C., Ni, Y., Zhao, M., Feng, C., Zhang, M. & Fan, Y. 2013. Biomechanism of impact resistance in the woodpecker's head and its application. – Science China Life Sciences 56(1): 715–719. DOI: 10.1007/s11427-013-4523-z

Xu, P., Ni, Y., Lu, S., Liu, S., Zhou, X. & Fan, Y. 2021. The cushioning function of woodpecker's jaw apparatus during the pecking process. – Computer Methods in Biomechanics and Biomedical Engineering 24(5): 527–537. DOI: 10.1080/10255842.2020.1838489

Yaraghi, N. A., Herrera, S., Sherman, V. R., Bushong, E. A., Ellisman, M. H., Kisailus, D. & McKittrick, J. 2016. Structural analysis of the tongue and hyoid apparatus in a woodpecker. – Acta Biomaterialia 37: 1–13. DOI: 10.1016/j.actbio.2016.03.030

Yoon, S. H. & Park, S. 2011. A mechanical analysis of Woodpecker drumming and its application to shock-absorbing systems. – Bioinspiration & Biomimetics 6(1): 016003. DOI: 10.1088/1748-3182/6/1/016003

Zelditch, M., Swiderski, D., Sheets, D. H. & Fink, W. 2004. Geometric Morphometrics for Biologists: A primer. – Elsevier Academic Press, Waltham, MA.

Ornis Hungarica 2023. 31(1): 126–132.
DOI: 10.2478/orhu-2023-0008

Praecarbo strigoniensis, a new genus and species of Cormorants (Phalacrocoracinae) from the Late Oligocene of Hungary

Jenő (Eugen) Kessler[1] & Ida Horváth[2]*

Received: January 03, 2022 – Revised: May 08, 2023 – Accepted: May 09, 2023

Kessler, J. (E.) & Horváth, I. 2023. *Praecarbo strigoniensis*, a new genus and species of Cormorants (Phalacrocoracinae) from the Late Oligocene of Hungary – Ornis Hungarica 31(1): 126–132. DOI: 10.2478/orhu-2023-0008

Abstract The authors describe a fossil avian distal *tibiotarsal* epiphysis, remains of a cormorant (Phalacrociracinae), differing in age and morphological characters from other fossil cormorants. The fossil material comes from sandy marine deposits from the village of Máriahalom in north-western Hungary, together with the remains of 26 other vertebrate species, mostly marine. The age of the fossiliferous deposit is established in the Late Oligocene, at the beginning of the Chattian stage (MP25–30). The earliest fossil specimens of the subfamily Phalacrocoracinae are known from the Early-Middle Oligocene of North America and Northeast Africa, respectively. The rest of the known specimens are dated to the Late-Upper Oligocene and Lower Miocene. Thus, the fossil described here represents an intermediate age and it is less specialised in morphological characteristics. A new genus and species of cormorants, *Praecarbo strigoniensis*is described here based on the distal epiphysis of a fossil *tibiotarsus*.

Keywords: NE Hungary, Máriahalom, Late Oligocene, cormorant, *tibiotarsus*

Összefoglalás A szerzők egy *tibiotarsus* disztális epifizisének vizsgálata során jutottak arra a következtetésre, hogy a lábszárcsont töredék kora és jellegei a későbbi kárókatona leletektől eltérők. A lelet az ÉNY-magyarországi Máriahalom település határában található tengeri homok üledékéből származik, 26 más állatfaj maradványaival együtt. A lelőhely korát az oligocén Katti emeletének (MP25–30) elejére sorolják. Mivel a Phalacrocoracinae alcsalád legkorábbi ismert fajai É-Amerika, illetve É-Afrika kora-középső oligocénjéből ismertek, a többiek meg már a késő-oligocén végéről és a miocén elejéről, a vizsgált maradvány korban egy köztes helyet foglal el, jellegeiben pedig kevésbé specializálódott. Az új genus és faj *Praecarbo sinogradiensis* n. gen. *et* sp. néven van leírva, egy *tibiotarsus* disztális epifiziséből.

Kulcsszavak: ÉNY-Magyarország, Máriahalom, Késő-Oligocén, kárókatona, *tibiotarsus*

[1] *Department of Paleontology, EötvösLoránd University, 1117 Budapest, Pázmány Péter sétány 1/c, Hungary*
[2] *University of Sopron, Faculty of Forestry, Institute of Wildlife Management and Biology, 9400 Sopron, Bajcsy-Zsilinszky utca 4., Hungary*
** corresponding author, e-mail: idahorvath03@gmail.com*

Introduction

Early representatives of the typical piscivorous family belong to the subfamily Graculavinae and are known with two species from the Paleocene of North America (*Graculavus velox* Marsh 1872 and *Graculavus pumilus* Marsh 1872) (Brodkorb 1963). The earliest member of the subfamily Phalacrocoracinae, which includes the fossil and extant cormorant species, is known from the Eocene in England (*Actiornis anglicus* Lydekker, 1891) (Brodkorb 1963), based on the proximal epiphysis of an *ulna*.

The genus *Phalacrocorax* was first recorded by R. W. Shufeldt in 1915 from the Early-Middle Oligocene of North America (USA) from the proximal part of a *carpometacarpus* (*Phalacrocorax mediterraneus* Shufeldt, 1915) (Brodkorb 1963). A *premaxilla* from the Jebel Qatrani Formation (Egypt, Fayum) has also been reported from the Rupelian (Rassmussen *et al*. 1987), and already from the Late Oligocene and Early Miocene representatives of the genus *Borocarbo* from France and Germany (Mayr 2001, 2007, 2009, Mourer-Chauviré *et al*. 2004, Göhlich & Mourer-Chauviré 2010). The remaining fossil cormorant species are known from the Neogene (Milne-Edwards 1863, Cheneval 1984, Mlíkovskỳ 2002). The distal *tibiotarsal* epiphysis is known in some of the species mentioned above, so we compare our material to them.

Description of the fossil site

Rabi and Botfalvai (2008) provided information about the fossil site, including data from Janssen (1984), who studied molluscs here.

Máriahalom is a small village in the NW Hungary, in Komárom-Esztergom county, 47 km from Budapest *(Figure 1)*. The fossiliferous site is on the outskirts of the village, and it consists of marine sands of the Mányi Formation. The mollusc-rich layers of the former sand mine, include many bones of aquatic vertebrates, as well as those from the surrounding land environment, carried into the sea by water currents.

Figure 1. Location of Máriahalom fossil site on the map of Hungary

1. ábra Máriahalom fosszilis lelőhely helye Magyarország térképén

Alongside the fossil remains of typical aquatic invertebrates, there are many selacine and skate teeth, bones of bony fish, turtles, crocodiles, and sirenians, as well as those of birds and other mammals. In 2008, 26 vertebrate species were reported from this fossil site, but their numbers have increased since then (Kessler 2013, 2018, Rabi *et al.* 2018).

Most of the vertebrate fossils were collected by Zoltán Evanics, amateur palaeontologist, who donated his collection to the Hungarian Natural History Museum in Budapest, and the avian bones were transferred to the Palaeontology Department of Eötvös Loránd

University. Several taxa (?*Grallavis* sp., ?Gaviiformes indet., ?*Balearica* sp., Aves indet.) (Kessler 2013) have been tentatively reported from this collection.Unfortunately, the condition of most bones is so precarious that they cannot be identified to species level, with two exceptions. First, a claw bone which belongs to the Osprey genus *(Pandion)* has been described as a new species, *Pandion pannonicus* (Kessler 2018).Second, the distal part of aphalacrocoracine *tibiotarsus* – which was initially reported erroneously as anatid – is the subject of the present study.

Material and Method

The material under study is a distal tibiotarsal epiphysis. We used the corresponding bone of a Great Cormorant *(Phalacrocorax carbo) (Figure 2: 1–10)* and the works of Göhlich and Maurer-Chauviré (2010) and Cheneval (1984) as comparative materials. The age of the fossiliferous deposit was dated to the Late Oligocene (MP25–30) at the beginning of the Chattian stage. Bone dimensions were measured with a digital calliper. Anatomical terminology was provided by the Osteological Handbook of Baumel *et al*. 1979.

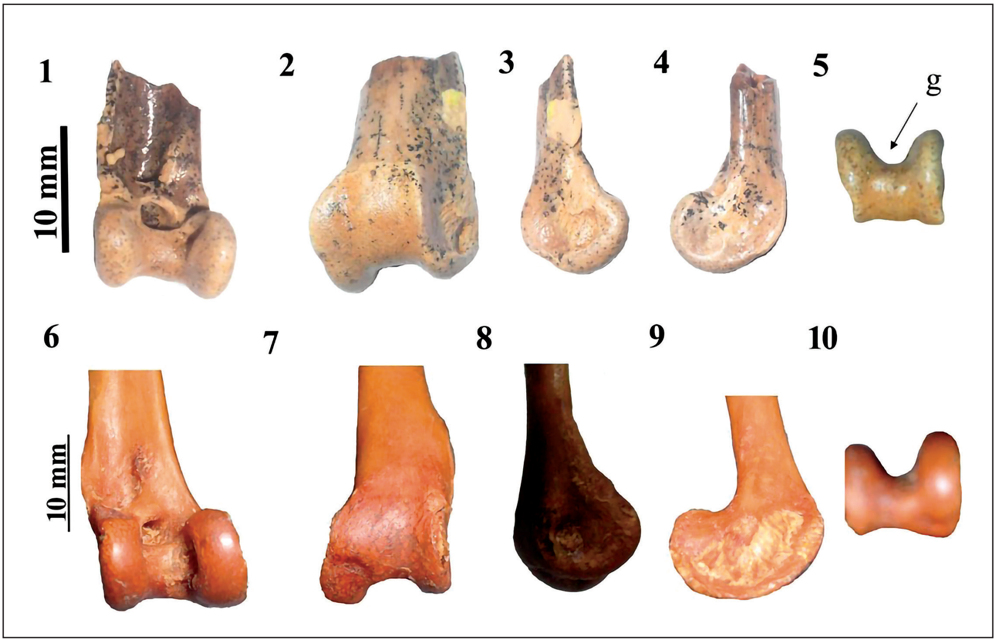


Figure 2. images 1–5. *Praecarbo strigoniensis* n. gen. *et* sp. 1. right *tibiotarsus*, distal epiphysis, cranial aspect; 2. caudal aspect; 3. medial aspect; 4. lateral aspect; 5. distal aspect; g. *incisura intercondylaris*; images 6–10. extans *Phalacrocorax carbo* L. 1758; 6. right *tibiotarsus*, distal epiphysis, cranial aspect; 7. caudal aspect; 8. lateral aspect; 9. medial aspect; 10. distal aspect

2. ábra 1–5. kép: *Praecarbo strigoniensis* n. gen. *et* sp. 1. jobboldali *tibiotarsus*, disztális epifizis, craniális nézet; 2. caudális nézet; 3. mediális nézet; 4. laterális nézet; 5. disztális nézet; g. *incisura intercondylaris*; 6–10. kép: recens *Phalacrocorax carbo* L. 1758; 6. jobboldali *tibiotarsus*, disztális epifizis, craniális nézet; 7. caudális nézet; 8. laterális nézet; 9. mediális nézet; 10. disztális nézet

The abbreviations used are F = width of the distal epiphysis; G1= thickness of the epiphysis at the medial condyle, G2 = thickness of the epiphysis at the lateral condyle, G= overall thickness of the distal epiphysis.

The bone was photographed from several views, with diagnostic characteristics indicated. Photos of extant species were also used for comparison.

Systematics

Class Aves Linnaeus, 1758
Order Pelecaniformes (Sharpe, 1891)
Family Phalacrocoracidae (Bonaparte, 1853)
Subfamily Phalacrocoracinae (Bobparte, 1854)
Genus: *Praecarbo* n. gen.
Species: *Praecarbo strigoniensis* n. sp.

Site and age: Máriahalom (Komárom-Esztergom county, Esztergom district, Hungary), Middle-Late Oligocene, (MP25–30), Mányi Formation.

Holotype: right *tibiotarsus*, distal epiphysis *(Figure 3: 1–4)*;

Dimensions: E-8.5 mm; F-10.88 mm; G1-4.60 mm; G2-4.75mm *(Figure 3: 5–7)*;

Dimensions of comparative materials: rec. *Phalacrocorax carbo* (Linnaeus, 1753) E-10.52 mm; F-12.91 mm; G1-5.43 mm; G2-7.17 mm; rec. *Nannopterum auritus* (Lesson, 1831) E-6.64 mm; F-12.72 mm; G-11.07 mm; *Microcarbo pygmeus* (Pallas, 1773) E-4.90 mm; F-7.70 mm; G-7.60 mm (orig.); *Borocarbo tardatus* Göhlich & Mourer-Chauviré 2010 E-7.30 mm; F-13.70 mm; G-12.50 mm; *Oligocorax litoralis* E-5.60 mm; F-9.60-9.90 mm; *Nectornis miocaenus* E-4.80 mm; F-8.60 mm; G-8.80 mm (after Göhlich & Mourer-Chauviré 2010); *Phalacrocorax litoralis* (Milne-Edwards, 1863) F-9.82–10.26 mm; (after Cheneval 1984).

Name etymology: *Praecarbo* = genus preceding *Phalacrocorax*; *strigoniensis* = from the Latin name of Esztergom (Strigonium).

Genus and species diagnosis: an early ancestor of cormorants with less specialised subfamily characters. Also lacking the medio-lateral distortion of the distal epiphysis, indicative of the members of the clade, which also gives the shape of the *sulcus extensorius* and *pons tendineus*:

- the *sulcus extensorius* (a) is wide and extends under the bridge in the middle of the epiphysis;
- the *pons tendineus* (b) is almost straight, quite wide, distalolaterally slightly oblique;
- the opening of the *canalis extensoius* (c) is wide;
- *tuberculum retinaculi m. fibularis* (d) slightly prominent;
- *condylus medialis* (e) and *condylus lateralis* (f) nearly equal in size;
- *incisura intercondylaris* (g) is wide and deep in distal view.

In comparison with the early cormorant species already mentioned, *the sulcus extensorius* of the Máriahalom specimen does not extend medially but remains in the middle of the diaphysis until the bridge; the *pons tendineus* is broader and less oblique than in *Oligocorax, Nectornis* and *Phalacrocorax,* and almost identical to *Borocarbo*; the *canalis extensorius*

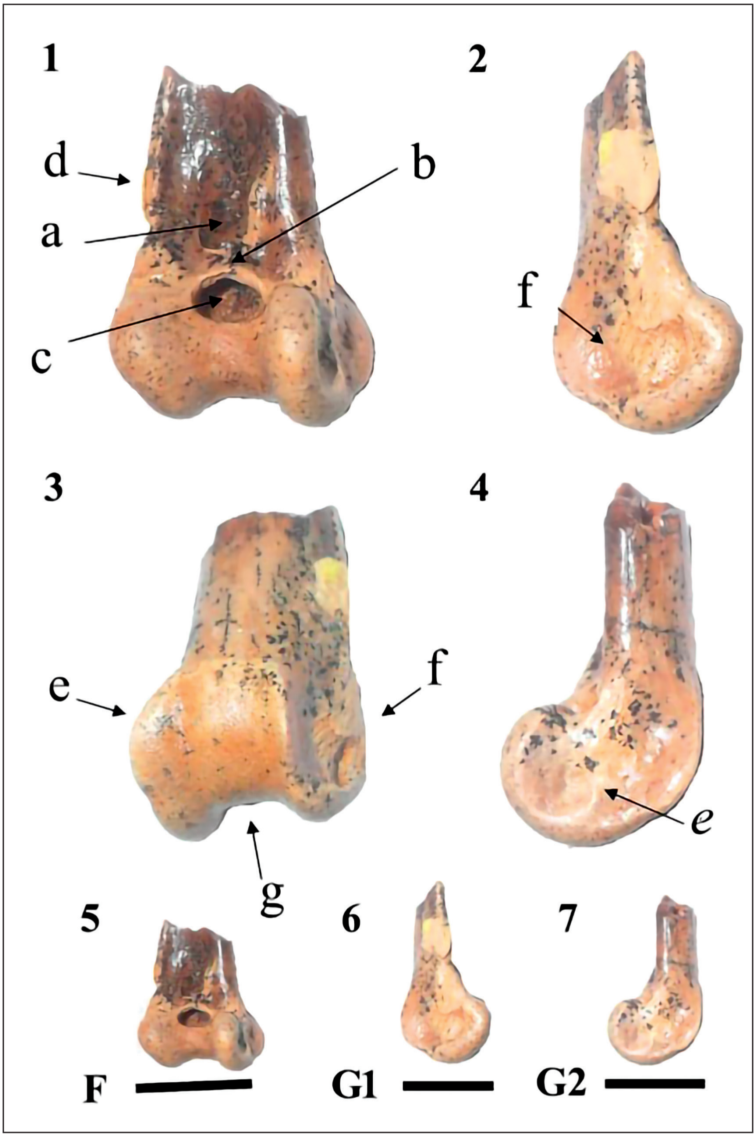


Figure 3. images 1–4. *Praecarbo strigoniensis* n. gen. *et* sp. 1. right *tibiotarsus*, distal epiphysis, cranial aspect, a – *sulcus extensorius*, b – *pons tendineus*, c – orifice traverse of *canalis extensorius*, d – *tuberositas musc. fibularis*; 2. caudal aspect, e – *condylus medialis*, f – *condylus lateralis*, g – *incisura intercondylaris*; 3. lateral aspect, f – *condylus lateralis*; 4. medial aspect, e – *condylus medialis*; images 5–7. measurement method: F – width of distal epiphysis; G1 – thickness of *lateral condylus*; G2 – thickness of *medial condylus*

3. ábra 1–4. kép *Praecarbo strigoniensis* n. gen. *et* sp. 1. jobboldali *tibiotarsus*, disztális epifizis, craniális nézet, a – *sulcus extensorius*, b – *pons tendineus*, c – *canalis extensorius* nyílása, d – *tuberositas musc. fibularis*; 2. caudális nézet, e – *condylus medialis*, f – *condylus lateralis,* g – *incisura intercondylaris*; 3. laterális nézet, f – *condylus lateralis*; 4. mediális nézet, e – *condylus medialis*; 5–7. kép: mérési módszer: F – disztális epifizis szélessége; G1 – laterális *condylus* vastagsága; G2 – mediális *condylus* vastagsága opening is similarly wide as in the other species; the length of the two articular cusps (*condylus medialis* and *lateral*) is almost identical, unlike in the other species, where the former is more or less longer; the *condylus medialis* is not oblique as in *Borocarbo*; the *incisura intercondylaris* is deeper than in *Oligocorax* and *Nectornis*.

In size, *Praecarbo* is slightly smaller than *Borocarbo tardatus*, *Phalacrocorax carbo,* and *Nannopterum auritus,* and larger than all the other above species. Further, it is probably dated earlier than the other fossil phalacrocoracine species with known tibiotarsus.

Conclusions

The above study describes a new genus and species based only on a distal tibiotarsal fragment, it is of serious importance. This finding signals an early appearance of phalacrocoracine birds in Europe and the Carpathian Basin in particular. It is characteristic that all known avian species in the Carpathian Basin during the Mesozoic, Palaeogene, and Early Neogene perdiodswere aquatic or at least lived in a wetland environment, indicating the palaeogeographic and palaeoclimatic conditions in this area at that time.

Acknowledgements

We thank Zoltán Evanics for the recovery of the fossil and the Palaeontology Department of Eötvös Loránd University for providing it for identification.

References

Baumel, J. J., King, A. S., Lucas, A. M., Breazile, J. E. & Evans, H. E. 1979. Nomina Anatomica Avium. – Academical Press, London

Brodkorb, P. 1963. Catalogue of fossil Birds. Part 1. (Archaeopterygiformes through Ardeiiformes). – Bulletin of Florida State Museum. Biological Sciences 7: 179–293.

Cheneval, J. 1984. Les oiseaux aquatiques (Galliformes to Anseriformes) du gisement aquitanien de Saint-Gérand-le-Puy (Allier, France) [The aquatic birds (GalliformestoAnseriformes) of the aquitanian deposits of Saint-Gérard-le-Puy (Allier)]. – Révision Systématique – Palaeovertebrata 14(2): 33–115. (in French)

Göhlich, U. B. & Mourer-Chauviré, C. 2010. A new cormorant-like bird (Aves: Phalacrocoracoidea) from the Early Miocene of Rauscheröd (Southern Germany). – Records of the Australian Museum 62: 61–70. DOI:10.3853/j.0067-1975.62.2010.1536

Janssen, A. W. 1984. Late Oligocene molluscs from a sand-pit near Máriahalom (Hungary). A Preliminary study. – Annales Universitatis Scientiarum Budapestinensis de Rolando Eötvös nominatae, Sectio Geologica 24: 109–150.

Kessler, E. 2013. A Kárpát-medence madárvilágának őslénytani kézikönyve [Paleontological Handbook of Birdlifein the Carpathian Basin]. – Könyvműhely, Miskolc (in Hungarian)

Kessler, E. 2018. Evolution and presence of diurnal predatory birds in the Carpathian Basin. – Ornis Hungarica 26(1): 102–123. DOI: 10.1515/orhu-2018-0008

Mayr, G. 2001. A cormorant from the late Oligocene of Enspel, Germany (Aves, Pelecaniformes, Phalacrocoracidae). – Senckenbergiana Lethaea 81(2): 329–333.

Mayr, G. 2007. A small representative of the Phalacrocoracoidea (cormorants and anhingas) from the Late Oligocene of Germany. – The Condor 109: 930–943. DOI: 10.1650/0010-5422

Mayr, G. 2009. A dwarf species of the Phalacrocoracoidea (cormorants and anhingas) from the Early Miocene of Germany. – Ibis 151(2): 392–395. DOI: 10.1111/j.1474-919X.2009.00920.x

Milne-Edwards, A. 1863. Mémoire sur la distribution géologique des oiseaux fossiles et description de quelques espèces nouvelles [Memorandum on the geological distribution of fossil birds and description of some new species]. – Annales des Sciences Naturelles (4)20: 132–176. (in French)

Mlíkovskỳ, J. 2002. Cenozoic Birds of the World, Part 1., Europe. – Ninox Press, Praha

Mourer-Chauviré, C., Berthet, D. & Hugueney, M. 2004. The late Oligocene birds of Créchy quarry (Allier, France), with a description of two new genera (Aves: Pelecaniformes: Phalacrocoracidae, and Anseriformes: Anseranatidae). – Senckenbergiana Lethaea 84(1–2): 303–315.

Rabi, M. & Botfalvai, M. 2008. A preliminary report on the Late Oligocene vertebrate fauna from Máriahalom, Hungary. – In: Galácz, A. (ed.) 125th Anniversary of the Department of Palaeontology at Budapest University. – A Jubilee Volume Hantkeniana 6: 177–185.

Rabi, M., Bastl, K., Botfalvai, G., Evanics, Z. & Peigné, S. 2018. A new carnivoran fauna from the Late Oligocene of Hungary. – Palaeobiodiversity and Palaeoenvironments 98(3): 509–521.

Rasmussen, D. T., Olson, S. L. & Simons, E. L. 1987. Fossil birds from the Oligocene Jebel Qatrani Formation, Fayum Province, Egypt. – Smithsonian Contributions to Paleobiology 62: 1–20.

sciendo

Ornis Hungarica 2023. 31(1): 133–146.
DOI: 10.2478/orhu-2023-0009

Variations in the spring migration of Eurasian Woodcock (*Scolopax rusticola* L.) in Hungary

Attila Bende*, Sándor Faragó & Richárd László

Received: February 16, 2023 – Revised: April 27, 2023 – Accepted: April 28, 2023

Bende, A., Faragó, S. & László, R. 2023. Variations in the spring migration of Eurasian Woodcock (*Scolopax rusticola* L.) in Hungary. – Ornis Hungarica 31(1): 133–146. DOI: 10.2478/orhu-2023-0009

Abstract We investigated the spatial and temporal patterns of migration of Eurasian Woodcock (n=23,539 specimens) collected in Hungary during spring sampling (2010–2019) in the framework of the Woodcock Bag Monitoring. There were differences in the temporal course of the spring migration of the species between the western and eastern regions of Hungary. In the western Hungarian counties, migration started earlier in all cases, while in Borsod-Abaúj-Zemplén county the main migration period – i.e. the period between the 25% and 75% cumulative sampling thresholds – started on average one week later than in Somogy county. We investigated the influence of weather factors on the spatial and temporal pattern of migration, in addition to geographical causes, based on the distribution of Péczely's macrosynoptic situations recorded the week before and after the migration peak. In years free of weather extremes, the migration period was characterised by neutral (80.0%) macrosynoptic situations, with unfavourable (9.5%) and favourable (10.5%) conditions occurring less frequently. In the years with weather anomalies (2013, 2016, 2018), unfavourable macrosynoptic situations (81.3%) determined the spring migration characteristics. Weather anomalies (macrosynoptic conditions with gale-force winds and heavy snowfall) affected the timing of spring migration, but regional differences were observed in all years regardless of weather conditions, suggesting that spring migration of Woodcock is phase-delayed in the southern Transdanubian and north-eastern regions of Hungary.

Keywords: woodcock migration, migration pattern, migration-weather correlation, macrosynoptic situations

Összefoglalás Az Erdei Szalonka Teríték Monitoring keretében tavaszi mintavétel során (2010–2019-es évek) Magyarországon gyűjtött erdei szalonkák (n=23539 pld.) vonulásának tér- és időbeli mintázatát vizsgáltuk. Eltérés mutatkozott a faj tavaszi vonulásának időbeli lefolyásában Magyarország nyugati és keleti régiója között. A nyugat-magyarországi vármegyékben a vonulás minden esetben korábban kezdődött, Somogy vármegyéhez képest Borsod-Abaúj-Zemplén vármegyében a fő vonulási időszak – vagyis a 25% és 75%-os kumulált mintavételi küszöbérték közé eső időszak – átlagosan egy hetes késéssel vette kezdetét. Megvizsgáltuk, hogy a földrajzi okok mellett az időjárási tényezők milyen hatást gyakorolnak a vonulás tér- és időmintázatára, amihez a vonulás tetőzést megelőző és az azt követő héten regisztrált Péczely-féle makroszinoptikus helyzetek megoszlását vettük alapul. Az időjárási szélsőségektől mentes években a vonulási időszakot a semleges (80,0%) makroszinoptikus helyzetek jellemezték, a kedvezőtlen (9,5%) és a kedvező (10,5%) állapotok ritkábban fordulnak elő. Az időjárási anomáliával terhelt években (2013, 2016, 2018) a kedvezőtlen makroszinoptikus helyzetek (81,3%) határozták meg a tavaszi vonulás karakterisztikáját. Az időjárási anomáliák (viharos széllel, jelentős havazással járó makroszinoptikus állapotok) a tavaszi szalonkavonulás időbeli lefolyására gyakoroltak hatást, azonban a regionális különbségek az időjárási viszonyoktól függetlenül minden évben jelentkeztek, tehát az erdei szalonka tavaszi vonulása Magyarország dunántúli és északkeleti régiójában fáziskéséssel zajlik le.

Kulcsszavak: szalonkavonulás, vonulás mintázat, vonulás-időjárás kapcsolata, makroszinoptikus helyzetek

Institute of Wildlife Biology and Management, Faculty of Forestry, University of Sopron, 9400 Sopron, Bajcsy-Zsilinszky utca 4., Hungary
** corresponding author, e-mail: bende.attila.@uni-sopron.hu*

Introduction

The Eurasian Woodcock breeds only occasionally in Hungary (Bende & László 2020, Hadarics 2021), so in our region, it is only seen in larger numbers during its autumn and spring migration. Hungary is located between the main nesting and wintering areas of the Woodcock, and thus, based on ringing data (Schally 2019, Bende 2021) and telemetry studies (Aradis 2015, Arizaga *et al*. 2015, Le Rest *et al*. 2018), birds migrating through our region come from several countries (France, Italy, Greece) and arrive along different routes. Based on the data of foreign ringed specimens marked in Hungary or found in our country, Woodcocks arrive in spring mainly from France and to a lesser extent from Italy (Bende 2021), so the weather conditions here are decisive for the start of migration. Regarding bird species' migration strategy, weather conditions play a key role (Alerstam 2011), especially when extreme conditions with stormy winds, heavy frost and intense precipitation events dominate (Liechti 2006, Shamoun-Baranes *et al*. 2017). As discussed above, weather conditions can have a significant impact on the starting of migration and its progression through feeding opportunities and resting periods (Jenni & Schaub 2003, Newton 2006), as well as, on the survival of specimens (Klaassen *et al*. 2014).

Several theories have been put forward concerning the factors that trigger the spring migration, the most in Hungary well-known of which is the theory developed by Schenk (1924), claiming that *"the migration starts with the first north-western cyclone in spring"*, i.e. the mass spring migration is induced by depression over the British Isles and high air pressure over southern Europe (Hegyfoki 1907, Schenk 1924, Pátkai 1951). The North Atlantic Oscillation (NAO) is one of the climatic variables, along with temperature, precipitation, and wind conditions, that have been most often investigated as a predictor of spring migration phenology (Haest *et al.* 2018). Larger-scale Hungarian studies on the migration characteristics of the species, in the framework of the Hungarian Woodcock Bag Monitoring between 1990 and 1999, were only carried out after almost seventy years (Faragó *et al*. 2000). During these examinations, however, no data were available that would have allowed a nationwide examination of the spatial and temporal characteristics of the migration, so the opinion of Schenk (1924), i.e. the spring migration of Woodcock in Hungary is phase-delayed, could neither be disproved nor confirmed. The year 2009 marked a turning point in Woodcock research, when the spring Woodcock hunting in Hungary was threatened by the enforcement of the European Union Birds Directive (79/409 EEC). As a condition for the deviation from the Directive, Hungarian Hunters' National Association launched the Hungarian Woodcock Bag Monitoring in 2009, which was joined in 2010 by the Institute of Wildlife Management and Vertebrate Zoology of the University of West Hungary with a biometric testing module. Owing to the new national monitoring, an exceptional opportunity was offered to examine the migration of Woodcock with time series based on a large sample (n=23,539), provided by more than 5,000 participants, following a standard protocol for a decade. This amount of data offered the opportunity to gain a picture of the spatial and temporal patterns of migration on a longer time scale and on a national scale, and the role of the major atmospheric phenomena that determine the weather of the Carpathian Basin in influencing migration.

Material and Method

From the spring of 2010, the Woodcock Bag Monitoring, under the coordination of the Hungarian Hunters' National Association, has set a target of up to 5,600 Woodcocks to be bagged annually. In addition to recording body sizes, the place where the birds were bagged (county, municipality, game manager), the exact time of sampling (month, day, hour, minute) and the sex of the birds were recorded. During the monitoring, more than 500 authorised hunters – with more than 800 sampling points – participated in data collection each year, which data were sent directly to the Institute of Wildlife Biology and Management of the University of West Hungary during the first five years (2010–2014). In the second phase of monitoring (2015–2019), the basic data sent by the hunters were forwarded to our institute by the staff of Szent István University. In order to evaluate the migration dynamics in a uniform way, the data sets of the sampling period from 1 March to 10 April (41 days) were analysed. In order to ensure uninterrupted observational data collection, during the first phase of monitoring (2010–2014), no sampling opportunity was available to data providers on Saturday mornings, and therefore data from the Saturday evening were excluded from the analysis.

In our studies, we based our results on the proven correlation that the temporal variation in the number of Woodcocks bagged is proportional to the variation in the number of birds migrating during the spring migration, thus, the collected samples faithfully reflect the spatial and temporal pattern of the spring migration of the Woodcock population in Hungary (Faragó *et al*. 2012a, 2012b, 2014, 2015a, 2015b, 2016, Schally 2020, Bende 2021). To characterise the temporal course of migration, we defined the main migration period in each year as the period between 25% and 75% cumulative sampling values. This allows us to determine the length of the period when migration is the most intense and 50% of the birds migrate through Hungary. The dates associated with the main migration period defined in this way allowed comparisons to be made between years, even at a finer spatial, regional or county level. Counties with a small number of annual items ($n < 30$) were not used for regional comparisons.

Statistical tests were conducted using a two-sample t-test to analyse the temporal differences between the eastern and western regions of the country during the main period of migration. Linear correlation analysis ($r_{25\%,}$ $r_{75\%}$) was also conducted to examine the correlation between the annual changes in the differences between the south-western and north-eastern regions of the country. For our statistical analyses, we chose Somogy county from the south-western region of Hungary, which has a large number of items, and Borsod-Abaúj-Zemplén county from the north-eastern region of Hungary, which also has a significant number of items. The regional time differences in the migration from Hungary by year were tested using a one-sample t-test, where we assumed that the empirical frequency average corresponds to 8 days for the average of the probability variable characterising the difference.

To examine the relationship between spring migration and weather, we used Péczely's classification system of large-scale weather situations, the data sets of the catalogue of macrosynoptic types (Károssy 2016). Four main centres of action play a role in the formation of low- and high-pressure atmospheric formations moving in the cellular structure of the temperate zone (Károssy 2016):

1. Icelandic low-pressure minimum,
2. Azores high-pressure maximum,
3. Persian Gulf low-pressure minimum,
4. Siberian high-pressure formation.

These centres of action determine the weather patterns on the continent in the short or even longer term. Our work is based on Péczely's classification system (1957, 1961) for Hungary, which classifies the weather of the Carpathian Basin into 13 types based on the air pressure values converted to sea level. When examining the relationship between bird migration and weather, particular importance is given to the formation of tropospheric atmospheric formations with a cellular structure, both vertically and horizontally, i.e. cyclonic and anticyclonic types, which Péczely considered to be separated at 1015 hPa threshold value. The frequency of wind directions and the orographic characteristics of the Carpathian Basin were also decisive factors in the classification (Péczely 1957, 1961).

The macrosynoptic conditions recorded in the week before and after the maximum of the spring migration of Woodcock were as follows:

I. North-guided meridional positions
- mCc: Backside flow system of a cyclone,
- AB: Anticyclone over the British Isles,

II. South-guided meridional positions
- mCw: Frontal flow system of a cyclone,
- Ae: Anticyclone to the east of Hungary,
- CMw: Frontal flow system of a Mediterranean cyclone,

III. Zonal west-guided positions
- zC: Zonal cyclonic flow,
- Aw: Anticyclone to the west of Hungary or incoming anticyclone from the west,
- As: Anticyclone to the south of Hungary

IV. Zonal east-guided positions
- An: Anticyclone to the north of Hungary,
- AF: Anticyclone over the Fenno-Scandinavia region,

V. Central anticyclone
- A: Anticyclone over the Carpathian Basin,
- C: Cyclone centre over the Carpathian Basin.

We classified these large-scale atmospheric formations into three groups (favourable, neutral, unfavourable) based on their impact on migration and compared their frequency with the bagging dynamics of the sample (n=23,539) collected during the study period (2010–2019). The classification criteria were based on the findings on atmospheric physical conditions affecting bird migration from Liechti (2006), Alerstam (2011), Ćiković and Radović (2013), Shamoun-Baranes *et al.* (2017) and Le Rest *et al.* (2018). Macrosynoptic conditions free of strong frosts, with favourable wind direction and no stormy winds and low atmospheric humidity were considered favourable, conditions free of extremes but not meeting the favourable criterion were considered neutral, and conditions with extreme, stormy, heavily foggy, strong frosts or intense precipitation events were considered unfavourable (Alerstam 1976). The goodness of fit test (χ^2) was used to check whether the macrosonoptical conditions of the years assumed to be average correspond to the average for the period 1958–2010. We also tested whether the macrosynoptic states recorded during the migration period of years considered extreme for bird migration were statistically verifiably different from the Péczely states of the average years, i.e. they could be considered extreme. In this case too, the goodness of fit test (χ^2) was applied. This is consistent with the method used by Gyurácz *et al.* (2010).

This classification is also in line with the finding of Le Rest *et al*. (2018) that only weather extremes had a significant effect on the migration of Woodcock and its interruption. Statistical analysis of the data was performed using Microsoft Excel 2016 and Statistica 13. For geospatial processing, chromatic maps were created using the geospatial software ArcGIS 10.3.

Results

The migration dynamics by regions

In the ten years examined, the main migration period in Borsod-Abaúj-Zemplén County started min. 3 days and max. 10 days later than in Somogy County. The county differences in the start and end sampling days of the main migration period in each year are well correlated ($r_{25\%} = 0.7867$, $r_{75\%} = 0.6568$), i.e. the time delay in the sampling days of the main period occurs in each year of the spring migration of the Woodcock *(Figures 1, 2)*.

The time difference between the beginning (day corresponding to a 25% cumulative sampling rate) and the end (day corresponding to a 75% cumulative sampling rate) of the main period between Somogy and Borsod-Abaúj Zemplén Counties was observed in each year. The difference observed was not significantly different over the period examined ($t = 2.1$, $df = 17$, $P = 0.404$). There was no statistically verifiable difference in the length of the main migration period between the counties examined in each year ($t = 2.1$, $df = 17$, $P = 0.277$).

In the south and west Hungarian counties, migration started earlier each year, with Baranya county typically reaching the 25% cumulative sampling rate first. In 2011, being the average year presented as an example, this date fell on 21 March. Compared to this start date, we examined the time delay in the other counties. In the counties of the southern and western Transdanubian region (Baranya, Zala, Somogy, Tolna Counties) and in north-western Hungary (Győr-Moson-Sopron County) the main migration period started at a similar time to the start date. In Vas county and in the Danube-Mountains region (Veszprém, Fejér and Komárom-Esztergom Counties), a two-day phase-delay was observed compared to the start date of the main period. In the North Hungarian Mountains region, and in some years in Komárom-Esztergom and Fejér Counties, a phase-delay of up to 5 days was recorded compared to the baseline date, which confirms the time delay – at a cumulative value of 50% and 75% too – of the Woodcock migration between the western and north-eastern regions of Hungary in all years studied *(Figures 3, 4)*.

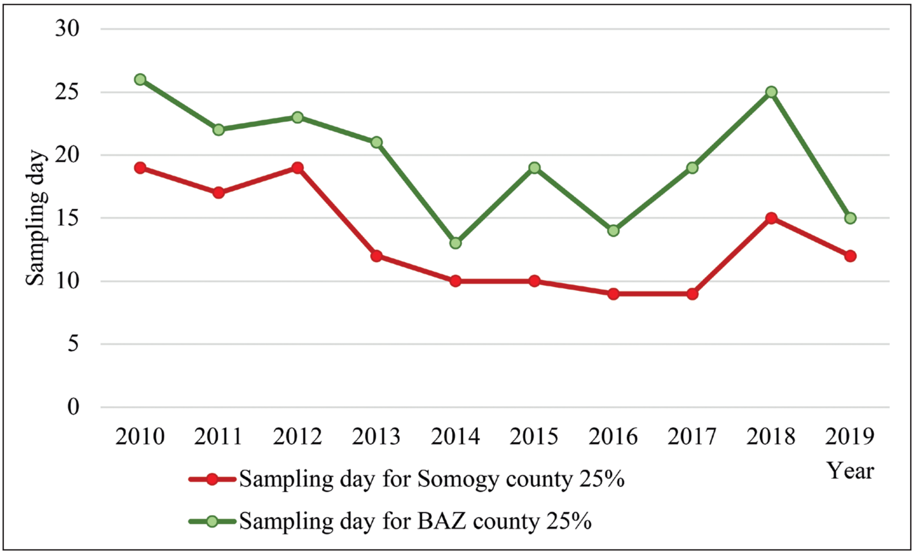


Figure 1. Sampling days indicating the beginning of the main migration period (25%) of Woodcock (*Scolopax rusticola* L.) in Somogy and Borsod-Abaúj-Zemplén (BAZ) counties in the years 2010–2019

1. ábra Az erdei szalonka (*Scolopax rusticola* L.) fő vonulási időszakának kezdetét (25%) mutató mintavételi nap a 2010 és 2019 közötti években Somogy és Borsod-Abaúj-Zemplén vármegyében

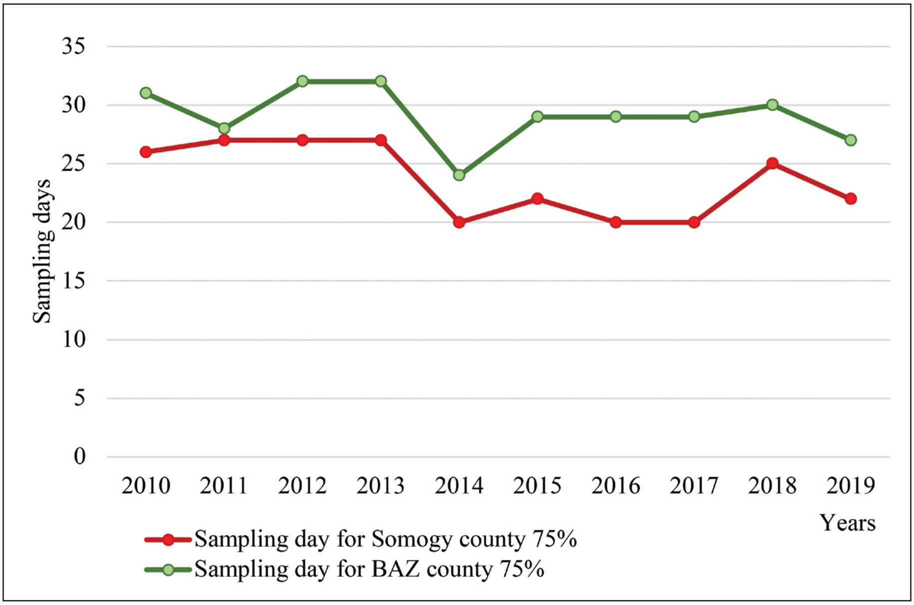


Figure 2. Sampling days indicating the beginning of the main migration period (75%) of Woodcock (*Scolopax rusticola* L.) in Somogy and Borsod-Abaúj-Zemplén (BAZ) counties in the years 2010–2019

2. ábra. Az erdei szalonka (*Scolopax rusticola* L.) fő vonulási időszakának kezdetét (75%) mutató mintavételi nap a 2010 és 2019 közötti években Somogy és Borsod-Abaúj-Zemplén vármegyében

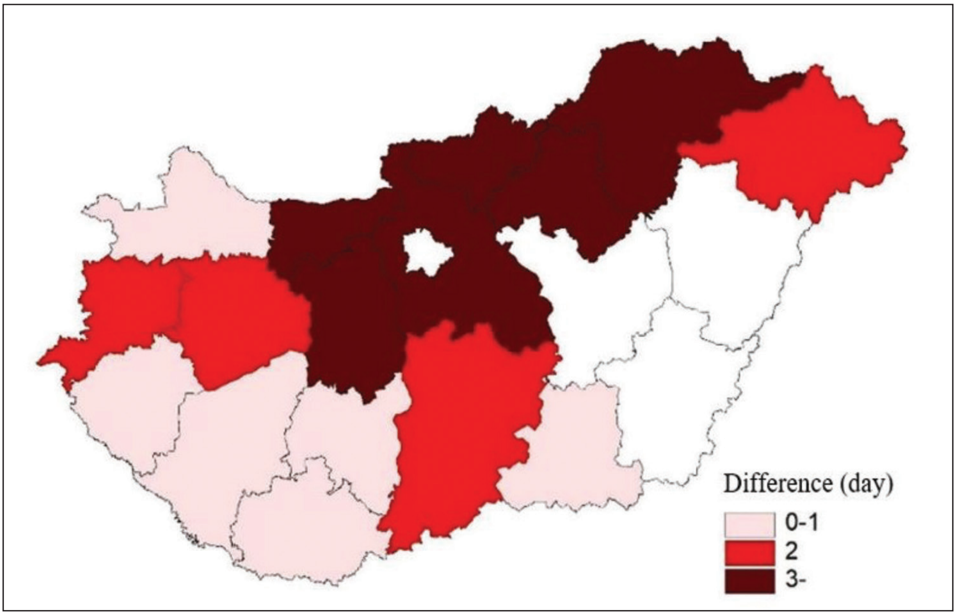


Figure 3. Temporal variation in the spring migration of Woodcock (*Scolopax rusticola* L.) between counties in 2011 based on dates associated with 50% cumulative sampling values

3. ábra Az erdei szalonka (*Scolopax rusticola* L.) tavaszi vonulásának időbeli eltérése az egyes megyék között 2011-ben az 50%-os kumulált mintavételi értékekhez tartozó időpontok alapján

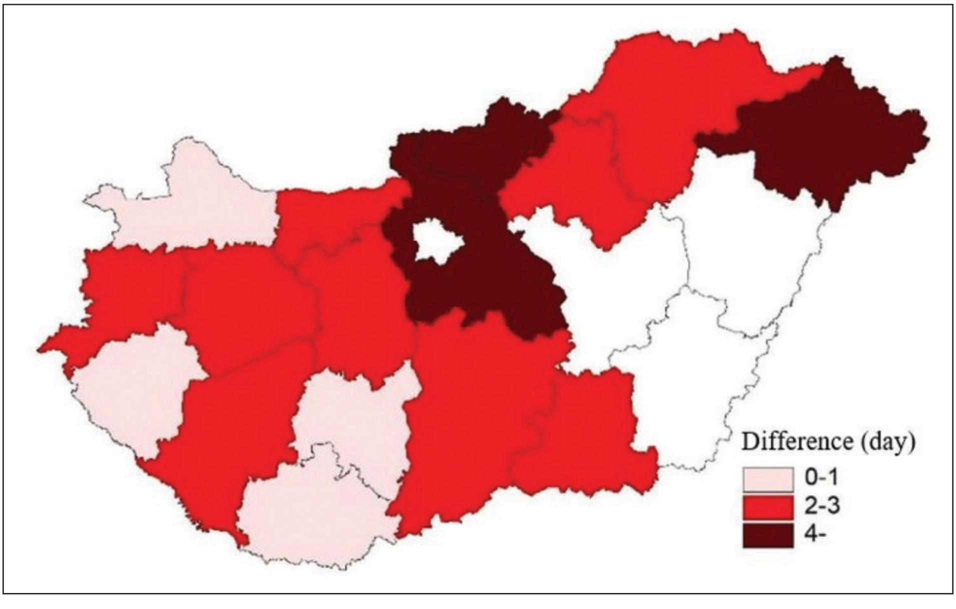


Figure 4. Temporal variation in the spring migration of Woodcock (*Scolopax rusticola* L.) between counties in 2011 based on dates corresponding to 75% cumulative sampling values

4. ábra Az erdei szalonka (*Scolopax rusticola* L.) tavaszi vonulásának időbeli eltérése az egyes megyék között 2011-ben a 75%-os kumulált mintavételi értékekhez tartozó időpontok alapján

The impact of weather on the spatial and temporal patterns of spring migration

Based on the frequency of Péczely's macrosynoptic situations in years with no extreme weather conditions, we found that the most typical states were the anticyclone over the British Isles (AB, 20.0%) and anticyclone to the west of Hungary or incoming anticyclone from the west (Aw, 15.2%). In the first case, an anticyclone develops in the North Sea region, transporting Arctic air into the Carpathian Basin with a northerly flow, while in the second case, the Azores anticyclone moves towards Central Europe, extending long in a west-east direction. In addition to the above, the backside flow system of a meridional cyclone (mCc, 11.4%), with the position of the anticyclone centre over west Europe or the Atlantic Ocean, and the Anticyclone of an east flow with an azonal-oriented anticyclone (An, 13.3%) over Poland were also dominant. Also typical was the macrosynoptic state of anticyclone to the east of Hungary (Ae, 8.6%), which only develops adverse conditions when the south-east flow intensifies to a storm or is accompanied by strong cooling. However, this macrosynoptic condition is generally characterised by variable directional and weak air movement, so it does not significantly affect the migration.

Among the centric anticyclones, the central Péczely-state (A, 7.6%) over the Carpathian Basin is the same as the Ae state. As in the two situations above, the synoptic state of the cyclonic centre over the Carpathian Basin (C, 3.8%) has no significant effect on the

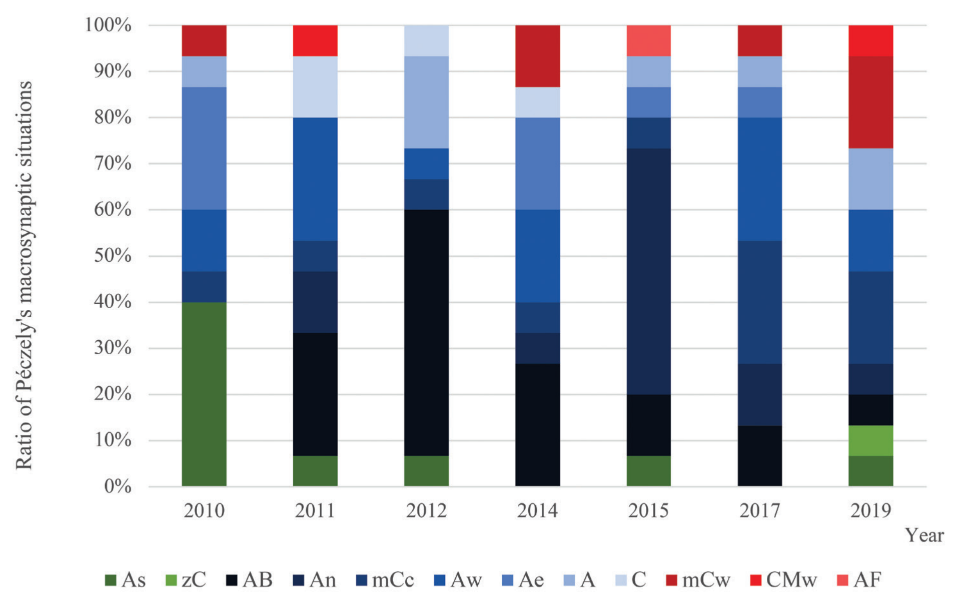


Figure 5. Proportion of Péczely's macrosynoptic situations during the most intensive phase of the spring migration of Woodcock (*Scolopax rusticola* L.) in years with normal migration (favourable – green, neutral – blue, unfavourable – red)

5. ábra A Péczely-féle makroszinoptikus állapotok aránya az erdei szalonka (*Scolopax rusticola* L.) tavaszi vonulásának legintenzívebb szakaszában a normál vonulással jellemezhető években (kedvező – zöld, semleges – kék, kedvezőtlen – piros) migration if the winds with variable direction are not stormy and there is no significant cooling.

These conditions are not considered particularly favourable, because the air currents that develop are typically from the north, but their absence of extremes (wind, temperature, precipitation) does not significantly affect the spring migration of Woodcock. The above conditions, which can be considered neutral, accounted for 80.0% of all macrosynoptic situations in years with average migration.

Zonal, west-guided flow systems create favourable conditions during the spring migration. The anticyclone south of Hungary (As, 9.5%) and the smallest zonal cyclonic flow (Zc, 1.0%) typically bring mild oceanic air waves to the Carpathian Basin. The proportion of truly favourable macrosynoptic situations with optimal atmospheric conditions was only 10.5% in the years with the average circulation.

Among the considerable snowfall, persistent frost, and stormy winds producing south-guided meridional positions of macrosynoptic situations with unfavourable atmospheric conditions for migration, the frontal flow system of a cyclone (mCw, 6.7%) and the frontal flow system of a Mediterranean cyclone (CMw, 1.9%) were the most common, with a smaller proportion of anticyclones (AF, 1.0%) over the equally unfavourable Fenno-Scandinavian region. In years with an average migration rate, the proportion of Péczely's situations with unfavourable conditions was only 9.5% *(Figure 5)*.

In the sampling periods of 2014 and 2019, the frequency of macrosynoptic conditions unfavourable for migration was higher. The migration period was characterised by a few days of non-extreme but unfavourable cyclonic activity (mCw, CMw, AF) – a cold front with repeatedly occurring stormy north-east winds – which did not have a marked impact on the length of the main period, as the adverse atmospheric conditions were only present for a short period of time and thus, did not significantly affect migration.

In contrast to the years of migration with no extreme weather conditions, 2013, 2016 and 2018 had a high proportion of extreme weather conditions that were unfavourable for migration, which had a significant impact on migration in these years *(Figure 6)*. The frontal flow system

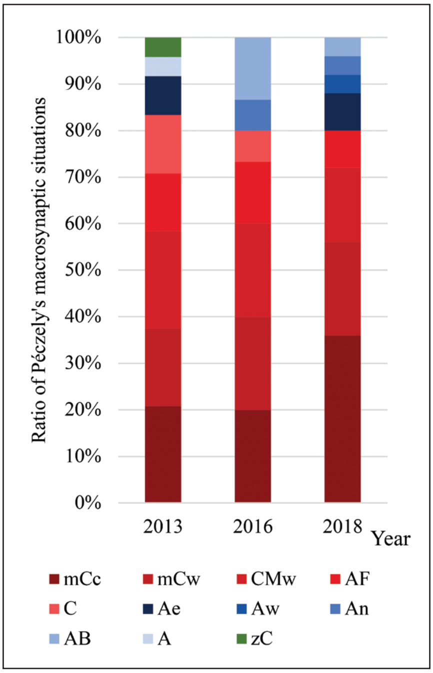


Figure 6. Ratio of Péczely's macrosynoptic situations during the most intense spring migration of Woodcock (*Scolopax rusticola* L.) in years with extreme weather conditions (favourable – green, neutral – blue, unfavourable – red)

6. ábra A Péczely-féle makroszinoptikus állapotok aránya az erdei szalonka (*Scolopax rusticola* L.) tavaszi vonulásának legintenzívebb szakaszában az időjárási szélsőségekkel jellemezhető években (kedvező – zöld, semleges – kék, kedvezőtlen – piros) of a Mediterranean cyclone (CMw, 18.8%) and the frontal flow system of a cyclone (mCw, 18.8%) macrosynoptic conditions resulted in heavy snowfall and stormy winds in our region. In addition to the above, the anticyclone (AF, 10.9%) over the Fenno-Scandinavian region had a significant impact in these two years, causing severe ground frosts. The influence of the cyclonic centre (C, 6.3%) over the Carpathian Basin was also important, which also produced strong cooling and stormy winds.

The high percentage of all these unfavourable macrosynoptic situations (81.3%) significantly affected the migration of Woodcock, especially during the most extreme spring of 2013. The overall proportion of macrosynoptic conditions creating neutral conditions was only 17.2% in these years, of which the anticyclone to the east of Hungary (Ae) condition was the most significant (6.3%). We compared the macrosynoptic positions of the average years with the average frequency of Péczely macrosynoptic positions between 1958 and 2010. Our results show that the distributions recorded in the years we considered as average were in line with the mean ($\chi^2 = 13.80$, df = 11, $P > 0.05$), while the distribution of Péczely states in the extreme years showed significant deviations ($\chi^2 = 45.26$, df = 11, $P > 0.05$).

There was no significant variation in the number of macrosynoptic states in the sampling periods studied, with an average of 7 states per period, but there was a significant variation in the distribution of states per year and their duration. In sampling periods with weather anomalies (2013, 2016, 2019) – when migration typically occurred under unfavourable macrosynoptic conditions (81.3%) – the average 8-day (SD = 1.62) main migration period recorded in normal years could be increased by up to 7 days (SD = 2.71), which means that in extreme weather conditions, birds may suspend migration in anticipation of improved atmospheric conditions, as they did in the spring of 2013, a year with extreme weather conditions, including stormy winds and heavy snowfall.

Discussion

In a mild spring, wintering grounds may start to be abandoned as early as mid-February, but the majority of Woodcocks do not leave their wintering grounds until 7–15 March. In the case of prolonged cold, winter-like weather, the start of migration may be postponed even later, up to mid-April (Clausager 1972, 1974, Bettmann 1975, Moritz & Nemetschek 1976). Based on spring sampling data from 2010-2019, the peak of migration of Woodcock in Hungary is typically between 16–24 March, which is consistent with previous data in the Hungarian literature (Schenk 1924, Pátkai 1951, Faragó 1985, Knefély 1987) suggesting that the mass arrival of Woodcock is in the last ten days of March.

The majority of the birds arriving in our region – based on the data of marked or foreign ringed Woodcocks found in our country – come from France (Schally 2019, Bende 2021) and first arrive in west Hungary. According to Schenk (1924), migrating Woodcock first reach the territory of the Kingdom of Hungary (before 1918) from the south-west (the Sava-Drava region), then continue in a north-east direction, leaving the northern ranges of the Carpathians, which fits well with the suggestion of Szabolcs (1971) that the spring migration takes place with a time delay in the whole territory of Hungary, starting in Baranya County and ending in the eastern region of the North Hungarian Mountains. The above findings – formulated in an empirical way – and the hypothesis of our own previous research (Faragó *et al*. 2012a, 2012b, 2014, 2015a, 2015b, 2016) were confirmed and clarified by the results of this study, thus clearly demonstrating that the migration of Woodcock in the western and north-eastern regions of Hungary is phase-delayed (Bende 2021). Satellite tagging research between wintering areas in Spain and nesting areas in Russia has shown that the species has an average daily migration distance of 174 km (100–256 km/day), so including stops (2–16 days), the spring migration – up to more than 5,000 km – lasts on average 40 days (24–62 days) (Arizaga *et al*. 2015). Sertić (2008) reported similar daily migration performance (maximum daily distance 200–300 km). The difference between the western and eastern regions of Hungary is min. 3 days; max. 10 days in years without weather extremes, which – taking into account rest periods – fits well with the migration performance determined by telemetry studies.

Our hypothesis – that the empirical frequency average corresponds to 8 days – about the mean of the probability variable characterising the difference between the western and eastern regions of the country was confirmed, i.e. there was no significant difference from the hypothesised frequency averages ($t = 1.7$, $df = 8$, $P = 0.5098$). The difference between the regions of the country is partly due to geographical reasons, as Woodcocks passing through our region have to travel more than 5,000 km by air in a straight line, but it can be assumed that there are other reasons for the differences besides geographical ones. Although the species necessarily leave forested areas during its migration and occurs in many habitats (Crespo *et al*. 2016), the availability of food plays an important role in the choice of resting sites and the length of time spent in forests (Duriez *et al*. 2005), and thus, feeding opportunities also influence migration.

In addition to the above, the spatial and temporal pattern of spring migration is most significantly influenced by weather factors. Our results show that during the peak migration period – in years without weather extremes – the macrosynoptic conditions were typically neutral for migration (80.0%) and only a minority of the macrosynoptic conditions were truly favourable (10.5%). Based on the results of previous domestic studies (Schenk 1924, 1931, Pátkai 1951) – and several foreign studies (Clarke 1912, Stadie 1938, Clausager 1972, Duchein 2019) – spring migration is most intense when the wintering area is cyclonic (Bruderer 1971, Beason 1978, Richardson 1990), which is confirmed by our results.

During the spring migration, the duration of stops is most affected by extreme weather conditions, which can lead to significant changes in the duration of the overall spring migration (Le Rest *et al*. 2018). Our results show that in years with extreme weather conditions, the 8-day main migration period can be up to a week longer than the average period in normal years. We hypothesise that this is because they may suspend their migration until atmospheric conditions are optimised. This is in accordance with the findings of studies that wind direction and strength are the primary influencing factors (Liechti 2006, Shamoun-Baranes *et al*. 2017). Intense precipitation events and strong (north, northeast) winds hinder migration, while the fog is more a side effect of the weather conditions that determine migration (Alerstam 1976). The results of 2013, 2016 and 2018 examined by us confirm the reduced migration intensity due to these extreme weather conditions.

Among the migration-favourable Péczely classes, migration-neutral conditions (65.3%) typically dominated in spring (1958–2010 average), while the proportion of situations with unfavourable atmospheric conditions was only 18.4% (Anagnostopoulou *et al.* 2019). Similar values were obtained for the frequency of Péczely values recorded in years considered as average, while a significant difference was observed in years with unfavourable migration and weather extremes.

The temporal repetition of the specific spatial components of synoptic systems is now a well-known process, and knowing their characteristics, it can be stated that the spring migration of Woodcock takes place under essentially neutral conditions. Our findings are in agreement with those of Bulte *et al.* (2014) and Kranstauber *et al.* (2015), who found that long-distance migratory species rarely experience wind conditions with optimal direction and speed throughout their journey, but usually exploited. As mentioned above, weather extremes have a significant impact on the temporal course and speed of passage through the region, but the regional differences we observed can be confirmed in all years regardless of weather conditions. The temporal differences between the eastern and western regions of Hungary in some years of the examined period (2010–2019) confirm previous findings that the spring migration of the species is phase-delayed between the south-western and western and north-eastern regions of the country.

Acknowledgement

The evaluation of the migration of the Woodcock was made possible by a monitoring programme coordinated by the Hungarian Hunters' National Association. We would like to thank the hunters who participated in the data reporting and helped us in our research in the framework of the Hungarian Woodcock Bag Monitoring. We would like to thank the reviewers of the paper and the editors of the journal for their valuable comments.

References

Alerstam, T. 1976. Bird Migration in Relation to Wind and Topography. – PhD dissertation, University of Lund. Sweden, Lund

Alerstam, T. 2011. Optimal bird migration revisited. – Journal of Ornithology 152(1): 5–23. DOI: 10.1007/s10336-011-0694-1

Anagnostopoulou, C., Károssy, Cs. & Makra, L. 2019. Egy automata és egy empirikus légcirkulációs osztályozási rendszer összehasonlító elemzése a Kárpát-medencére [Comparative analysis of an automatic and an empirical air circulation classification system for the Carpathian Basin]. – Földrajzi Közlemények 143(1): 71–88. (in Hungarian)

Aradis, A. 2015. La beccaccia in italia: approfondimenti sul ruolo dell'italia nella strategia migratoria e di svernamento per la specie [The Woodcock in Italy: insights into the role of Italy in the migratory and wintering strategy for the species]. – PhD dissertation, Università degli Studi di Palermo, Dottorato di Ricerca in "Biologia Ambientale e Biodiversità", Italy, Palermo (in Italian)

Arizaga, J., Crespo, A., Telletxea, I., Ibáñez, R., Díez, F., Tobar, J. F., Minondo, M., Ibarrola, Z., Fuente, J. J. C. & Pérez, J. A. 2015. Solar/Argos PTTs contradict ring-recovery analyses: Woodcocks wintering in Spain are found to breed further east than previously stated. – Journal of Ornithology 156(2): 515–523. DOI: 10.1007/s10336-014-1152-7.

Beason, R. C. 1978. The influences of weather and topography on water bird migration in the Southwestern United States. – Oecologia 32: 153–169. DOI: 10.1007/BF00366069.

Bende, A. 2021. Az erdei szalonka (*Scolopax rusticola* L.) tavaszi vonulásdinamikája, kor-, ivarviszonyai és költésbiológiája Magyarországon [Spring migration dynamics, age and sex ratio, and breeding biology of the Woodcock (*Scolopax rusticola* L.) in Hungary]. –PhD dissertation, Soproni Egyetem, Roth Gyula Erdészeti és Vadgazdálkodási Doktori Iskola. Magyarország, Sopron (in Hungarian)

Bende, A. & László, R. 2020. Woodcock (*Scolopax rusticola* L.) nesting in Hungary from the second half of the 19th century to the present day. – Ornis Hungarica 28(1): 92–103. DOI: 10.2478/orhu-2020-0007

Bettmann, H. 1975. Die Waldschnepfe [The Woodcock]. – 2. überarbeitete Auflage. München: BLV Verlagsgesellschaft (in German)

Bruderer, B. 1971. Radarbeobachtungen über den Frühlingszug im Schweizerischen Mittelland [Radar observations of spring migration on the Swiss Plateau]. – Ornitologischen Beobobachtungen 68: 89–158. (in German)

Bulte, M., McLaren, J. D., Bairlein, F., Bouten, W., Schmaljohann, H. & Shamoun-Baranes, J. 2014. Can wheatears weather the Atlantic? Modelling nonstop trans-Atlantic flights of a small migratory songbird. – The Auk 131(3): 363–370. DOI: 10.1642/AUK-13-233.1.

Clarke, W. E. 1912. Studies in Bird Migration. – Gurney and Jackson, Oliver and Boyd, London

Clausager, I. 1972. Skovsneppen som Ynglefugl i Danmark [The Woodcock as a young bird in Denmark]. – Danske Viltundersogelser 19: 1–39. (in Danish)

Clausager, I. 1974. Migration of Scandinavian Woodcock *(Scolopax rusticola)* with special reference to Denmark. – Danish Review of Game Biology 8: 38.

Crespo, A., Rodrigues, M., Telletxea, I., Ibánez, R., Díez, F., Tobar, J. F. & Arizaga, J. 2016. No habitat selection during spring migration at a meso-scale range across mosaic landscapes: a case study with the Woodcock *(Scolopax rusticola)*. – PLoS One 11: e0149790. DOI: 10.1371/journal.pone.0149790

Duchein, P. 2019. Migration de la Bécasse en Suisse 1998–2018, «20 ans d'observations et de suivis» [Woodcock migration in Switzerland 1998–2018, «20 years of observations and monitoring»]. – Etude réalisée par l'Association Suisse des Bécassiers (in French)

Duriez, O., Ferrand, Y., Binet, F., Corda, E., Gossmann, F. & Fritz, H. 2005. Habitat selection of the Eurasian Woodcock in winter in relation to Earthworms availability. – Biological Conservation 122: 479–490. DOI: 10.1016/j.biocon.2004.08.011

Faragó, S. 1985. Trends of Woodcock hunting bags in Hungary during the last 15 years. – IWRB-WSRG Newsletter 11: 33–39.

Faragó, S., László, R. & Bende, A. 2012a Az erdei szalonka *(Scolopax rusticola)* teríték monitoring eredményei 2010-ben Magyarországon [Results of the Hungarian Woodcock *(Scolopax rusticola)* Bag Monitoring in 2010]. – Magyar Vízivad Közlemények 22: 285–296. (in Hungarian and English)

Faragó, S., László, R. & Bende, A. 2012b Az erdei szalonka *(Scolopax rusticola)* teríték monitoring eredményei 2011-ben Magyarországon [Results of the Hungarian Woodcock *(Scolopax rusticola)* Bag Monitoring in 2011]. – Magyar Vízivad Közlemények 22: 297–310. (in Hungarian and English)

Faragó, S., László, R. & Bende, A. 2014. Az erdei szalonka *(Scolopax rusticola)* teríték monitoring eredményei 2012-ben Magyarországon [Results of the Hungarian Woodcock *(Scolopax rusticola)* Bag Monitoring in 2012]. – Magyar Vízivad Közlemények 24: 283–295. (in Hungarian and English)

Faragó, S., László, R. & Bende, A. 2015a Az erdei szalonka *(Scolopax rusticola)* teríték monitoring eredményei 2013-ban Magyarországon [Results of the Hungarian Woodcock *(Scolopax rusticola)* Bag Monitoring in 2013]. – Magyar Vízivad Közlemények 25: 289–302. (in Hungarian and English)

Faragó, S., László, R. & Bende, A. 2015b Development of the Woodcock *(Scolopax rusticola)* sex ratio in Hungary between 2010–2014. – In: Bidló, A. & Facskó, F. (eds.) V. Kari Tudományos Konferencia. Sopron, 2015.10.25. Konferencia Kiadvány, Nyugat-magyarországi Egyetem, Soproni Egyetem Kiadó, pp. 105–107.

Faragó, S., László, R. & Bende, A. 2016. Az erdei szalonka *(Scolopax rusticola)* teríték monitoring eredményei 2014-ben Magyarországon [Results of the Hungarian Woodcock *(Scolopax rusticola)* bag monitoring in 2014]. – Magyar Vízivad Közlemények 27: 284–296. (in Hungarian and English)

Faragó, S., László, R. & Sándor, Gy. 2000. Az erdei szalonka *(Scolopax rusticola)* testméretei, ivari és korviszonyai 1990–1999 között Magyarországon [Body dimensions, age and sex ratio of Woodcock *(Scolopax rusticola)* in Hungary between 1990–1999]. – Magyar Vízivad Közlemények 6: 409–461. (in Hungarian and English)

Gyurácz, J., Horváth, G., Csörgő, T., Bank, L. & Palkó, S. 2010. Influence of macrosynoptic weather situation on the autumn migration of birds in Hungary. – The Ring 25(1–2): 18–36. DOI: 10.2478/v10050-008-0071-5

Haest, B., Hüppop, O. & Bairlein, F. 2018. Challenging a 15-year old claim: The North Atlantic Oscillation index as a predictor of spring migration phenology of birds. Global Change Biology 24(4): 1523–1537. DOI: 10.1111/gcb.14023

Hadarics, T. 2021. Erdei szalonka *Scolopax rusticola* Linnaeus, 1758, Eurasian Woodcock. – In: Szép, T., Csörgő, T., Halmos, G., Lovászi, P., Nagy, K. & Schmidt, A. (eds.) Magyarország Madáratlasza, Bird Atlas of Hungary. – Agrárminisztérium, Magyar Madártani és Természetvédelmi Egyesület, Budapest, pp. 247–248. (in Hungarian with English Summary)

Hegyfoki, K. 1907. A madárvonulás és az idő. – Vogelzug und Wetter [Bird migration and weather]. – Aquila 1–4: 137–174. (in Hungarian and German)

Jenni, L. & Schaub, M. 2003. Behavioural and physiological reactions to environmental variation in bird migration: a review. – In: Berthold, P., Gwinner, E. & Sonnenschein, E. (eds.) Avian Migration. – Springer Berlin / Heidelberg, pp. 155–171. DOI: 10.1007/978-3-662-05957-9_10

Károssy, Cs. Á. 2016. A Kárpát-medence Péczely-féle makroszinoptikus időjárási helyzeteinek katalógusa 1881–2015. [Catalogue of the Péczely macrosynoptic weather situations of the Carpathian Basin 1881–2015.]. – Oskar Kiadó, Dozmat (in Hungarian)

Klaassen, R. H. G., Hake, M., Strandberg, R., Koks, B., Trierweiler, C., Exo, K. M., Bairlein, F. & Alerstam, T. 2014. When and where does mortality occur in migratory birds? Direct evidence from long-term satellite tracking of raptors. – Journal of Animal Ecology 83: 176–184. DOI:10.1111/1365-2656.12135

Knefély, M. 1987. Szalonkavarázs V. [Woodcock mystery V.]. – Nimród 107(3): 7–9. (in Hungarian)

Kranstauber, B., Weinzierl, R., Wikelski, M. & Safi, K. 2015. Global aerial flyways allow efficient travelling. – Ecology Letters 18: 1338–1345. DOI: 10.1111/ele.12528

Le Rest, K., Hoodless, A., Heward, Ch. & Cazenave, J-L. 2018. Effect of weather conditions on the spring migration of Eurasian Woodcock and consequences for breeding. – Ibis 161(S1): 559–572. DOI: 10.1111/ibi.12657.

Liechti, F. 2006. Birds: Blowin' by the wind? – Journal of Ornithology 147: 202–211. DOI 10.1007/s10336-006-0061-9.

Moritz, D. & Nemetschek, G. 1976. Der Zug der Waldschnepfe auf Helgoland [The migration of the Woodcock on Heligoland]. – Corax 5: 176–191. (in German)

Newton, I. 2006. Can conditions experienced during migration limit the population levels of birds? – Journal of Ornithology 147: 146–166. DOI: 10.1007/s10336-006-0058-4 (in English)

Pátkai, I. 1951. Az erdei szalonka vonulása 1947. és 1948. évek tavaszán. – Migration of the Woodcock in the spring of the years 1947 and 1948. – Пролет вальдшнепов весной 1947 и 1948 гг одов. – Aquila 55–58: 109–111, 111–112, 112–113. (in Hungarian, English and Russian)

Péczely, Gy. 1957. Áramlási helyzetek Magyarországon különböző makroszinoptikus helyzetekben [Flow situations in Hungary in different macrosynoptic situations]. – Időjárás 61: 408. (in Hungarian)

Péczely, Gy. 1961. Magyarország makroszinoptikus helyzeteinek éghajlati jellemzése [Climatic characterisation of macrosynoptic positions in Hungary]. – Országos Meteorológiai Szolgálat, Budapest (in Hungarian)

Richardson, W. J. 1990. Timing of bird migration in relation to weather: Updated review. – Oikos 30: 224–272. DOI: 10.1007/978-3-642-74542-3_6.

Schally, G. 2019. Assessment of the breeding and wintering sites of Eurasian Woodcock *(Scolopax rusticola)* occurring in Hungary based on ringing recovery data. – Ornis Hungarica 27(1): 110–116. DOI: 10.2478/orhu-2019-0007.

Schally, G. 2020. Az erdei szalonka *(Scolopax rusticola)* megfigyelési és elejtési adatainak vizsgálata Magyarországon 2009–2018 között [Analysis of observation and hunting bag data of Eurasian Woodcock (*Scolopax rusticola* Linnaeus, 1758) in Hungary between 2009–2018]. – PhD dissertation, Szent István Egyetem, Állattenyésztés-tudományi Doktori Iskola, Magyarország, Gödöllő (in Hungarian)

Schenk, J. 1924. Az erdei szalonka vonulása Európában – Der Zug der Waldschnepfe in Europa [Woodcock migration in Europe]. – Aquila 30–31: 26–74, 75–120. (in Hungarian and German)

Sertić, D. 2008. Lov na divljač i lovačka etika [Hunting and hunting ethics]. – Veleučilište u Karlovcu, Karlovac (in Croatian)

Shamoun-Baranes, J., Liechti, F. & Vansteelant, W. M. G. 2017. Atmospheric conditions create freeways, detours and tailbacks for migrating birds. – Journal of Comparative Physiology A. 203: 509–529. DOI: 10.1007/s00359-017-1181-9.

Stadie, R. 1938. Groß-Wetterlage und Frühjahrsschnepfenzug 1934 im Reich [Large-scale weather conditions and spring Woodcock migration 1934 in the Reich]. – Vereins Schlesischer Ornithologen 23: 1–6. (in German)

Szabolcs, J. 1971. Az erdei szalonka [The Woodcock]. – Mezőgazdasági Kiadó, Budapest (in Hungarian)

Ornis Hungarica 2023. 31(1): 147–162.
DOI: 10.2478/orhu-2023-0010

The Common Rock Thrush *(Monticola saxatilis)* in the Carpathian Basin

László Bozó[1] & Tibor Csörgő[2]

Received: February 16, 2023 – Revised: March 22, 2023 – Accepted: March 23, 2023

Bozó, L. & Csörgő, T. 2023. The Common Rock Thrush *(Monticola saxatilis)* in the Carpathian Basin. – Ornis Hungarica 31(1): 147–162. DOI: 10.2478/orhu-2023-0010

Abstract The Common Rock Thrush *(Monticola saxatilis)* is a species with an extremly large distribution range. Its European population is the strongest in the Mediterranean, but it also breeds in Central Europe. It still nests in small numbers in the Carpathian Basin, but has become extinct as a breeder in Hungary, where it was never a common species. In the present study, we summarised the occurrences of the species in the Carpathian Basin published in the literature. In the late 19th and early 20th centuries, a large amount of observational data on the spring migration of the species was collected, which allowed us to describe the migration phenology of that time. The Common Rock Thrush bred in small numbers in mountainous areas of Hungary, in natural habitats and in mines, vineyards and orchards. The collapse of the population occurred in the 1970s, but thereafter a few pairs bred in Hungary until the 2010s. Very few published records were found in Slovakia and Romania, which does not give a true picture of its former distribution there. However, its population has also declined drastically in Romania and it has become extinct as nesting species in Slovakia. The exact cause of the decline cannot be determined and several explanations have been proposed in recent decades. It is likely that the Carpathian Basin population, which is considered to be an edge-population, has been more exposed to negative changes, such as climate change, chemical inputs or changes in wintering grounds. A century earlier, the median date of the first spring returns was mid-April, but sometimes it was observed as early as late March. Nowadays, vagrant individuals have been observed again several times in Hungary, which gives us some hope for the future.

Keywords: agricultural landuse, climate change, habitat degradation, Rufous-tailed Rock-thrush, Blue Rock Thrush

Összefoglalás A kövirigó *(Monticola saxatilis)* hatalmas elterjedési területtel rendelkező faj. Európai állománya a Mediterráneumban a legerősebb, de Közép-Európában is költ. A Kárpát-medencében kis számban ma is fészkel, Magyarországról azonban – ahol sohasem számított gyakori fajnak – kipusztult, mint fészkelő. Jelen tanulmányban összegeztük a faj szakirodalomban publikált Kárpát-medencei előfordulásait. A 19. század végén és a 20. század elején sok megfigyelési adat gyűlt össze a kövirigó tavaszi vonulására vonatkozóan, amelyek segítségével lehetőségünk volt leírni az akkori vonulási fenológiát. A korabeli adatok alapján a faj kis számban költött Magyarország hegyvidéki területein, természetes élőhelyeken és bányákban, szőlőültetvényeken, gyümölcsösökben. Az állomány összeomlása az 1970-es években következett be, de ezt követően egészen a 2010-es évekig költött néhány pár az országban. Szlovákiában és Romániában nagyon kevés publikált adatát találtuk, ami nem ad valós képet egykori elterjedéséről. Állománya azonban Romániában is drasztikusan lecsökkent, Szlovákiából pedig kipusztult a fészkelők közül. Az állománycsökkenés okára az elmúlt évtizedekben több magyarázat is született. Valószínű, hogy a perempopulációnak számító Kárpát-medencei állomány sokkal jobban ki volt téve a negatív változásoknak, mint például a klímaváltozás, a vegyszerezés vagy a telelőterületeken bekövetkezett változások hatásainak. Egy évszázaddal korábban az első tavaszi visszaérkezések mediánja április közepére esett, de olykor már március végén is megfigyelték. Napjainkban Magyarországon ismét többször megfigyelték kóborló egyedeit, ami némi bizakodásra adhat okot a jövőre nézve.

Kulcsszavak: kövirigó, kék kövirigó, mezőgazdasági területhasználat, élőhelyek degradációja, klímaváltozás

[1] *Department of Systematic Zoology and Ecology, Eötvös Loránd University, 1117 Budapest, Pázmány Péter sétány 1/C, Hungary*
[2] *Department of Anatomy, Cell- and Developmental Biology, Eötvös Loránd University, 1117 Budapest, Pázmány Péter sétány 1/C, Hungary*
** corresponding author, e-mail: bozolaszlo91@gmail.com*

Introduction

The Common Rock Thrush is an insectivorous bird species whose breeding range extends from NW Africa, through the Mediterranean and the mountains of Central Europe to China (Collar & Bonan 2020). In Europe, its population is concentrated in the mountainous areas of the southern part of the continent. Turkey accounts for 65% of the total European population. Its distribution in the Carpathians is fragmented (Volet & Keller 2020). Population density decreases northwards (Grangé *et al.* 2015). It is strongly associated with mountain areas during migration, where it colonises both lower and higher altitudes (Volet & Keller 2020). Its global population is stable and is currently classified as Least Concern (BirdLife International 2023). In general, its nesting population trend is declining in Europe (Volet & Keller 2020). However, it has been reintroduced to southern Germany in the early 2000s (Bauer *et al.* 2003). In recent decades, there has been a significant population decline in the Appennines, the Carpathians and Moldova, where it has become extinct as a breeder, as in Hungary and Slovakia. In addition to the effects of climate change, habitat degradation and the disappearance of grazing may be behind the decline (Volet & Keller 2020).

Long-distance migrant. All populations wintering in tropical parts of Africa, mainly in E Africa (Collar & Bonan 2020). The spring migration of the European population lasts from March to May, with a peak in late March and early April, while in autumn it starts its migration with a dispersal movement in August and continues until the end of September. In spring, males can sometimes arrive at breeding sites as early as the end of February (Shirihai & Svensson 2018). Individuals from Asian populations migrate across the Red Sea to their wintering grounds in Africa. These populations also leave the breeding grounds in August, and in Kazakhstan and Tajikistan, the last individuals disappear by the end of September. Migrants can be seen in Arabia and along the Red Sea between late August and late November. In spring, they reach the mountainous regions of Kazakhstan and Central Asia in early May (Collar & Bonan 2020). Recent observations suggest that they also appear in southern and western India during autumn migration, suggesting that they also fly across the Indian Ocean (Balar *et al.* 2016, Abhinav & Dogra 2020).

In the Carpathian Basin, it nested mainly in operating and abandoned andesite or basalt mines, dolomite and limestone rocks, but also in vineyards and orchards (Schmidt 2000, Haraszthy 2019). Chernel (1899) recorded breeding in house wall cavities in the 1880s, while after the Second World War, it may have bred in ruined buildings in Budapest (Schmidt 2000). The former population of the Carpathian Basin typically bred only once a year, with replacement breeding in case of destruction, but occasionally two breeding attempts occurred. The clutches were mostly complete in the first two-three weeks of May, and the number of eggs was usually 4–6. The birds hatched after 13–14 days and were not independent even at three weeks of age (Haraszthy 2019).

According to Szombath (1944), it was most common in Transylvania, also nested in the Mátra, Bükk, Bakony, Pilis, Buda Hills and Mecsek. In the 1950s it was found in all suitable habitats in Hungary. It nested sporadically in karst, rocky areas, quarries, and vineyards (Keve 1984). Its population has gradually declined since then and by the late 1970s it was considered a rarity. The Hungarian population was estimated to be 15–25 pairs in the 1990s with regular breeding populations in Bükk, Zemplén Hills and Tokaj Hill (Magyar *et al.* 1998, Schmidt 2000), and 1–5 pairs in the 2000s (Hadarics & Zalai 2008). In the latter period, it bred regularly only in the Bükk (Hadarics & Zalai 2008), while by the end of the 2010s, it was considered extinct as breeder (Gál 2021). Its last confirmed nesting was in the Zemplén Hills in 2003, but it may have bred on Bél-kő in 2007 (Gál 2021). According to some authors, the disappearance was attributed to the changes in the wintering grounds in Africa (Schmidt 1995).

The aim of the present study was to collect the past and present occurrences of the Common Rock Thrush in the Carpathian Basin, especially in Hungary, that have ever been published. The large amount of data from the late 19th and early 20th century also allowed us an assessment of the species' migration based on contemporary data.

Material and Methods

We reviewed the most important Hungarian ornithological journals (A Puszta, Aquila, Bíbic, Calandrella, Cinege, Kócsag, Madártani Tájékoztató, Madártávlat, Ornis Hungarica, Túzok), the most important summary books as well as the website of the Hungarian field ornithologists (www.birding.hu). We have also used all the literature on the species cited in the Hungarian Ornithological Bibliography (Réthy 1980). Until the mid-1920s, a number of migration data were published *(Supplemental material 1)*, while afterwards mainly nesting records were mentioned. During the period between 1894 and 1926, the Royal Hungarian Ornithological Centre coordinated a data collection covering the entire Carpathian Basin under the leadership of Otto Herman and Jakab Schenk. During data collection, birdwatchers recorded the date of the first spring return of migratory bird species. Based on the published migration data, we calculated the median date of spring migration of the species, and gave the earliest and latest return dates. Based on the published breeding data, it was possible to process the former distribution of the species by geographical regions. As most of the data from the Carpathian Basin since the mid-20th century are from Hungary, we mainly present data from this country, but also data from the Slovakian, Ukrainen, Romanian, Serbian and Austrian parts of the Carpathian Basin are used. We have also collected data on Common Rock Thrush in the Hungarian oological collections using Haraszthy (2015).

Results

Spring migration data 1898–1923

Of the spring migration data between 1898–1923 (142 observations in total), 38.0% (n=54) were from the Slovakian, 28.2% (n=40) from the Romanian, 24.6% (n=35) from the Hungarian, and the remaining observations (9.9%, n=14) were from the Austrian, Serbian and Ukrainen part of the Carpathian Basin *(Figure 1*, *Supplemental material 1)*.

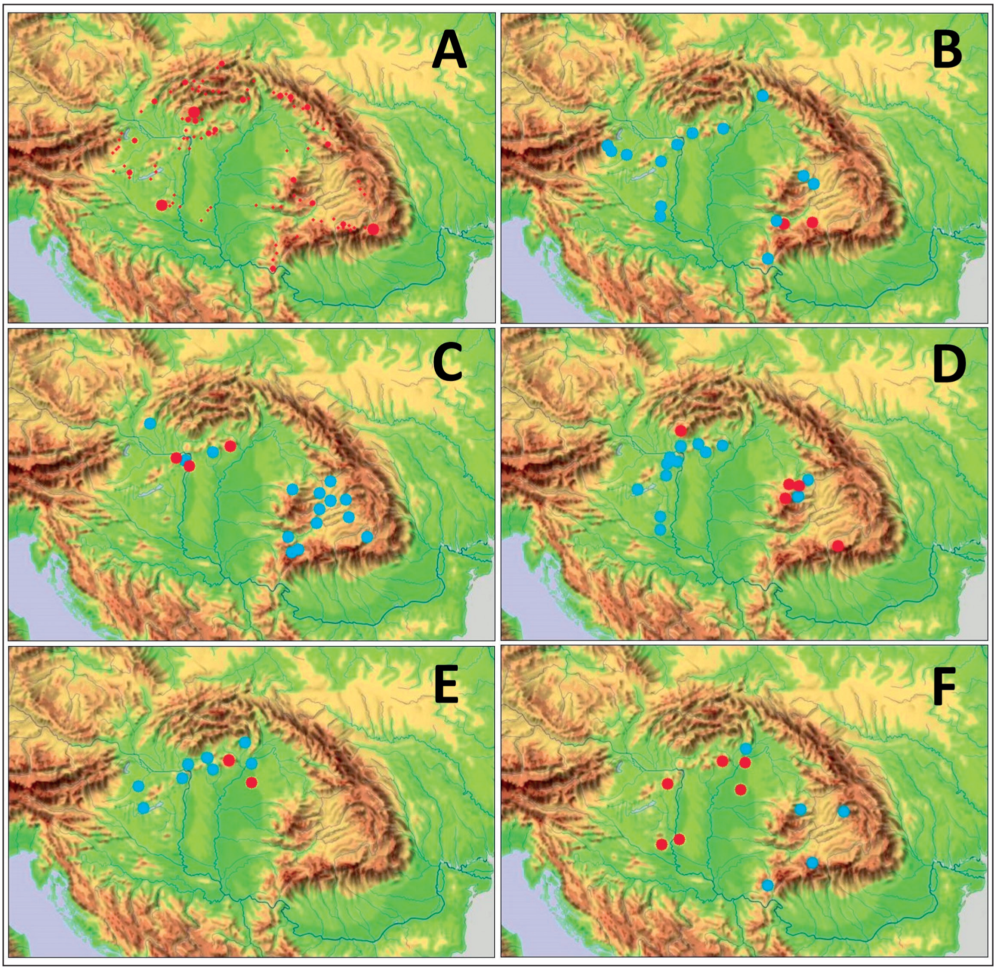


Figure 1. Spring observations from 1898 to 1923 (small: one observation at the given location, middle: 2–4 observations at the given location, large: 5–9 observations at the given location) (A), and field observations (red dots) and nestings (blue dots) from 1840–1925 (B), 1926–1950 (C), 1951–1975 (D), 1976–2000 (E) and 2000–2023 (F) in the Carpathian Basin

1. ábra Az 1898 és 1923 közötti tavaszi megfigyelések (kis kör: egy megfigyelés, közepes pont: 2–4 megfigyelés, nagy pont: 5–9 megfigyelés) (A), valamint az 1840–1925 (B), 1926–1950 (C), az 1951–1975 (D), az 1976–2000 (E) és a 2000–2023 (F) közötti terepi megfigyelési (piros pontok) és fészkelési (kék pontok) adatok a Kárpát-medence területéről

The median date of the first return of this species was 17 April (SD = 13.21 days), while the peak return period was between 11–30 April *(Figure 2)*. In terms of first sightings, the earliest record was on 20 March 1902, 1911 and 1912, and the latest on 15 May 1908.

Data on oological collections

In total, eight broods can be found in the Hungarian oological collections *(Table 1)*.

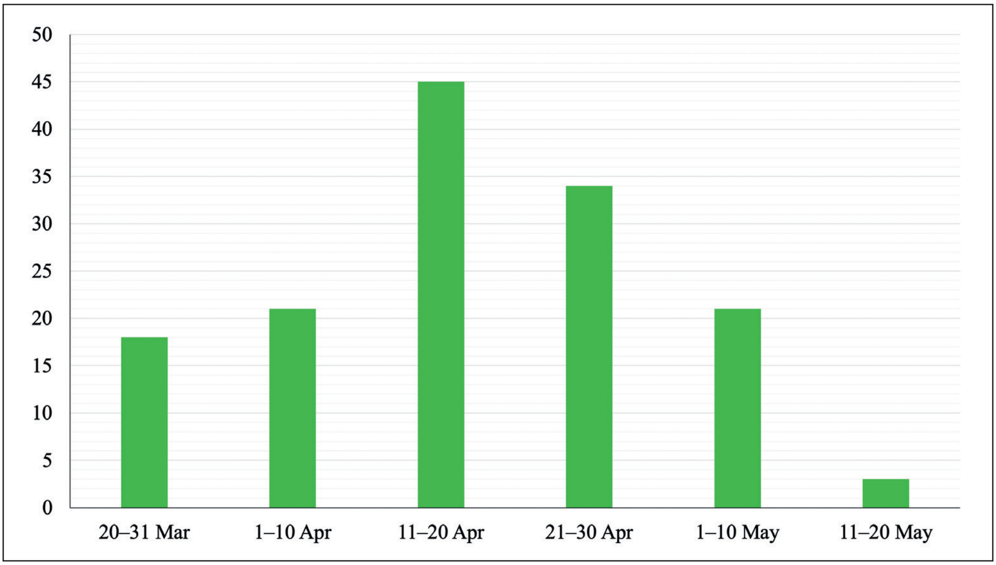


Figure 2. The spring migration data of the Common Rock Thrush between 1898 and 1923
2. ábra A kövirigó tavaszi dekádonkénti visszaérkezési ideje 1898 és 1923 között a Kárpát-medencében

Table 1. Broods can be found in the Hungarian oological collections
1. táblázat A magyarországi tojásgyűjteményekben található kövirigó-fészekaljak adatai

No. of eggs	Place of collection	Date of collection	Name of collector
5	Pécs	11 Jun 1949	Szilárd Cseresnyés
6	Pécs	01 Jun 1952	Szilárd Cseresnyés
5	Pécs	22 May 1953	Márton Németh
5	Pilisszentkereszt	27 May 1926	Frigyes Cerva
5	Budakeszi	25 May 1930	Dezső Szalók-Navratil
5	Magyarürög	27 Apr 1952	Szilárd Cseresnyés
5	Csór	17 May 1953	László Máté
5	Budakeszi	13 May 1934	?

Observation data

Hungary

A male was shot on 6 May 1894 in Cák, Vas County (Csaba 1963), and the species bred there then and in 1895 (Fromm 1929). In 1884, 1 pair nested in the castle moat at Kőszeg (Chernel 1899). A nest was found in Ság Hill on 12 July 1979, but no previous records have been reported from that area (Faragó 1981, Gyurácz & Kóta 2020). In May 1988, a nest was found in Mesteri, on a rock wall (Gyurácz & Kóta 2020) *(Figure 1)*.

On 26 April 1905 a migrating individual was seen at Balatonboglár. This was the first sighting of the species in the Balaton region, previously it had only been observed breeding in Inota (Csörgey 1905). In the early 1970s, in Badacsony, only 1–2 pairs were breeding in the basalt quarry, while previously it had also nested in the vineyards (1 June 1952, two feeding males) (Schmidt 1972a). Also here, 4–5 pairs used to nest annually, but in the 1990s, only one pair bred (Schmidt 1980, 1994). A male was seen on Szentgyörgy Hill in the Tapolca Basin on 1 June 1980 (Nagy 1980) *(Figure 1)*.

According to Agárdi (1942), it nested on three occasions in E Mecsek: on 1 June 1909 in a quarry under cultivation, on 26 April 1919 in the wall of a demolished press house, and once in the wall of the castle garden. In 1955, an individual was observed for several days in the disused chimney of a sawmill in E Mecsek, and it was considered likely that it had nested there (Péterfay 1957). In May and June 1918, it was heard singing several times in the vicinity of the National Theatre and Town Hall of Pécs, and probably nested there (Radetzky 1919) *(Figure 1)*.

In 1905 it was breeding in the Villány Hills (Csörgey 1905). In 1960 it was an uniformly widespread breeder in the area (Csaba 1963). On 20 April 2022 a male was seen in Nagyharsány on Szársomlyó (www.birding.hu) *(Figure 1)*.

Dorning (1944) mentions that in 1834 it was a widespread breeder in the Buda Hills. It also nested here later, for example on Sashegy in May 1926 and in the quarry on Kis-Gellérthegy in early May 1927. It was not seen here before May, but Madarász sighted it as early as 16 April 1881. He wrote that in recent years the population of the species had declined considerably in the vicinity of Budapest, e.g. due to disturbance by construction works and the activities of egg collectors. On 20 September 1943, an individual was seen in the Eskü square in Budapest. A nest was found near Nagymaros on 13 May 1954 (Kiss 1955). According to Sághy (1955), it nested in the quarries of the Gerecse. On 8 June 1954, Bókai (1955) found two nests at Pilisvörösvár, 60 m apart. One of them had four and the other five chicks. One of the males also had a ring, which was ringed locally on 15 April 1951 by the author. A juvenile was also captured at the same site on 1 August 1954 and was ringed on 8 June as a juvenile sitting in a nest about 2 km from the capture site also by the author. Bókai (1957) studied the behaviour of the species in detail. He was observed breeding in the early 1950s in the Buda Hills, Dunabogdány, Pilisvörösvár, and in the Kis- and Nagy-Kevély areas. The population was larger and denser in the volcanic mountains than in dolomite rocks. It was assumed that the adult males and females arrived at the breeding site in pairs. In 1971 a pair raised two broods in Budaörs (Schmidt 1972b). In 1937, Sághy (1968) observed a juvenile in the Diósvölgy quarry in Süttő, while no sightings were made in the red marble quarries in Tardos. In Budaörs and its surroundings, 5–6 pairs nested regularly in the 1950s, but since the mid-1960s only one pair has been recorded, and since 1978, it has disappeared as a breeder (Schmidt 1980, 1994). In 1975, the following nesting population were recorded in the vicinity of Budapest: Budaörs 1, Dunabogdány 3, Gánt 4, Páty 1, Pilisvörösvár 1, Remeteszurdok 1, Sóskút 2 pairs (Schmidt 1976). One pair was observed on the Sashegy in Budapest on 6 May 1976 (Simig 1978). One bird was sighted in Budakalász on 10 August 1980 (Anonymus 1981b), and another vagrant individual in Vértesboglár on 13–14 May 2017 (MME NB 2017) *(Figure 1)*.

It nested in the Velence Hills between 1958 and 1967 (Radetzky 1979) *(Figure 1)*.

Between 4 and 8 August 1958, a female was observed several times in Börzsöny (Gárdonyi 1958). Between 1968 and 1979, breeding was rare in the Börzsöny (Homoki-Nagy 1980). A feeding pair and one male were observed in the same area on 3 June 1977. On 21 June 1979 a nest with four eggs was found. On 29 May 1978, one male and on 19 May 1979, two males and one female were observed in the area (Dénes 1979) *(Figure 1)*.

A few pairs bred every year in the 1920s on the Szanda Hill, Cserhát (Habán 1959) *(Figure 1)*.

According to Moskát (1975), it was a sporadic nesting species in the Karancs-Medves in basalt, andesite and rhyolite quarries, in castle ruins and rocky hillsides. On 3 September 1972, 10–12 individuals were seen moving in the quarry at Eresztvény. It also nested in the Medves according to Varga (1980). By the early 1980s, it had ceased breeding in the area (Varga 1984) *(Figure 1)*.

In the Mátra, between 1949–1954, a stable population bred in abandoned mines, on the rocky streamsides and stony pastures. In 1948, seven pairs nested on the border of Gyöngyössolymos, nine in 1949, eight in 1950, eleven in 1951, nine in 1952, seven in 1953 and two in 1954. The author highlighted the weather and hunting as the reasons for the decline (Nagy 1955). Three males were seen on the Sár Hill in Gyöngyös on 24 April 1980 (Anonymus 1980) *(Figure 1)*.

On 12 July 1923, a female with a hatched young was clearly seen on the Diósgyőr castle ruins (Mauks 1924). In the same place, the species was observed several times in 1955 during the breeding season. In the same year, two pairs were observed breeding in the Mexikói-völgy near Miskolc (Bársony 1957). Mauks (1928) also observed an individual in the limestone quarry above the bathing resort of Görömböly – Tapolca, at the eastern foot of the Bükk Mountains on 13 May 1926. One bird was sighted at Bél-kő on 5 July 1980 (Anonymus 1981a), where the species was also observed during breeding season between 2005 and 2007 (www.birding.hu), but its breeding was not confirmed in neither case (Gál 2021). Another individual was sighted on 20 August 2010 (MME NB 2013, but the data was not validated by the Hungarian Rarities Committee). An immature bird was found in Miskolc, also in the Bükk, on 26 August 2020 (MME NB 2020) *(Figure 1)*.

It also bred in an abandoned mine in the Torna Karst (Dandl & Tömösváry 1978) *(Figure 1)*.

According to Mercsák and Mercsák (1980), several pairs bred in the abandoned quarries of the Nagy-Kopasz Hill in Tokaj in 1979. In the same area, two males died in vineyards between 10 and 15 May 1980 as a result of pesticide spraying (Mercsák 1980). Also in Tokaj in 1982, seven pairs were definitely breeding in 8 out of 25 different quarries, and breeding of two other pairs was uncertain. In that year, the author did not receive breeding data from other parts of the country (Mercsák 1983). The last observation of the species (male) from Tokaj was on 17 May 2000 (www.birding.hu) *(Figure 1)*.

It was observed in Békéscsaba in spring 1894 (Tarján 1930). A male was observed at Hortobágy Fishponds on 4 August 1992 (Konyhás 1993, 2004). Hadarics and Zalai (2008) mention its occurrence on the Hevesi plain without any specific data. On 30 March 2020, one male was seen in Debrecen, followed by another individual on 6 April (Endes 2019, data not accepted by the Hungarian Rarities Committee, MME NB 2020). On 6 May 2022, a male was observed near Baja (www.birding.hu) *(Figure 1)*.

Transylvania, Romania

The bird collection of the Bethlen College in Aiud, organised by Miklós Zeyk, included two specimens taken on 20 April 1845 in Kakova, while Elek Buda's collection included also two specimens taken on 5 May 1846 in Vajdahunyad (Schenk 1916). In 1916 it was only sighted in June near Sibiu (Mannsberg 1918). According to Miklós Zeyk, it was not uncommon in rocky and crevice areas. It was also seen in small numbers in high mountains, sometimes above the pine belt. It was found nesting on the cliffs of Tur, Torda, Torocko and Kakova, and also breeding on the Várhegy in Deva (Schenk 1920). Around the 1930s, the birds' spring arrival period in Transylvania was typically between 8–10 April, but sometimes they were seen as early as the end of March. In several areas of Transylvania, in the northeastern tip of Maros-Torda County, along the upper reaches of the Nyárád and Kisküküllő rivers, in many parts of Udvarhely County, in a few pairs in Csík at the eastern foot of the Harghita, below the Nagy-Hagymás, in the immediate vicinity of Brasov, in the gorge of Tömös, at the foot of the Suller Mountains. He has also observed the species on Mamuth Hill near Gyulafehérvár, in the gorges of Poklos, near Aiud, in the Torda and Túr rifts, at several points on the Királyhágó, near Deva, on the rocky slope above the Őrváralja, near Hátszeg and above Malomvíz at the foothill of the Retyezát. However, it has not been recorded on the Paring, Seben and Fogaras Mountains (Dobay 1935). Korodi Gál (1959) observed a family of five individuals on the eastern side of Bélavára on 18 June 1957. He had collected only one male from the area of Vladeasa. According to Béldi and Mannsberg (1970), it occurred in open rocky areas along the Kis-Szamos river. It was also recorded in similar localities (Sólyomkő, Bacsitorok) during migration in the hilly areas (21 and 28 April). In recent times, the species only breed in Torockó-Székelykő, Torda, Csalhó and Cserna Valley. The total Romanian breeding population is estimated by 45–200 pairs (Fântână *et al.* 2021) *(Figure 1)*.

Slovakia

It occurred in small numbers in the Tavarna region. It bred in the walls of the castle ruins of Csicsvaalja in 1911 (four chicks on 4 June) and in 1913 (five chicks in July) (Szeőts 1922). According to Turcek (1942), it nested in the vicinity of Vágújhely. Turcek (1959) observed it on 10 May 1958 in Szitnya, Selmecbánya *(Figure 1)*.

Discussion

The Common Rock Thrush was probably never a common species in Hungary (Csörgő & Gyurácz 2009), as confirmed by the fact that the earliest sources we found (e.g. Chernel 1899) did not mention Hungary as a regular nesting area, in contrast to the mountainous areas of the Carpathian Basin in Slovakia and Romania. However, as time progresses, the spring observation records from the late 19th and early 20th centuries include more and more records from Hungary. The increase in the number of sightings does not correspond to an increase in the population of the species, but is due to the expansion of the observation network. In the mountainous areas where it nested later in the 20th century, it was probably already breeding at that time. In Hungary, it also nested in the Alpokalja, Villány Hills, Mecsek, the Transdanubien Mountains and the Northern Mountains. Interestingly, although the last confirmed nesting was in the Zemplén Hills in 2003, no occurrences were previously reported from there.

Several sightings of the spring migration have been made in lowland and hilly areas where it does not bred. Similar observations were made later in the 20th and 21th centuries, indicating that the species can occur anywhere during migration. The most recent observations are probably the result of spring overshoot, but in the past, individuals from the Carpathian Basin population appeared regularly, if not in large numbers, in other parts of the region. A century ago, the first individuals appeared in the Carpathian Basin as early as the end of March, and the peak of migration was in mid-April. These data are consistent with the general migration patterns of the species in Europe (Collar & Bonan 2020).

There are very few published data on its autumn migration. The few observations suggest that individuals of the former population were sometimes still present on breeding grounds in early August, and by September they were very rare. The latest observation we found was on 20 September 1943, which also fits in with the European migration of the species (Collar & Bonan 2020).

The exact cause of the drastic decline of the species in the Carpathian Basin and its complete extinction in some countries (Slovakia, Hungary) is not known. According to Schmidt (2000), no changes occurred in the Hungarian breeding sites that would have justified the decline of the species, so he considered that the cause of the decline was linked to changes in the wintering grounds (poisoning of insects) or natural fluctuations in the population. This is supported by a comparison with the related species, the Blue Rock Thrush *(M. solitarius)*, which uses similar habitats, is also insectivorous and has a similar distribution range to the Common Rock Thrush in Europe. The main difference between the two species is that a significant proportion of the Blue Rock Thrush's population remains on nesting sites in winter, rather than migrating (Collar 2020). This species is expanding in Europe in general, most likely due to warmer weather in higher mountainous areas as a result of climate change (Pedrocchi 2020). Climate change is likely to be changing the species' distribution area, with its range shifting further north (Gál 2021). A similar process is currently taking place in the case of the Black-headed Bunting *(Emberiza melanocephala)* (Kókay 2021). Comparing the status and life history of the two species in Europe, it seems that changes in wintering sites or on migration routes may play an important role in the decline of the Common Rock Thrush. The picture is somewhat nuanced by the fact that other populations of the species in the vicinity, which presumably use the same wintering grounds, are stable (Volet & Keller 2020). This is because the Carpathian Basin population is only an edge population and negative impacts, even if not strong, affect these populations first.

Volet and Keller (2020) mention habitat conversion due to climate change and the abandonment of grazing as a background mechanism, but this could not be a significant influencing factor in the Carpathian Basin. Mercsák (1980) drew attention to the fact that chemical treatments in vineyards had locally completely forces to extinction the species.

The decline of insects may already be a locally influencing factor, and as the decline of the species largely affects its western populations, it is likely that the disappearance of the species may have been caused by increasingly intensive agriculture. As there are examples of reintroduction of the species in certain geographical regions (Bauer *et al.* 2003), in the long term, a reduction in chemical use may lead to positive changes in the population.

The reason for the disappearance of the Common Rock Thrush from the largest part of the Carpathian Basin is not clear, but the fact that the species has been observed several times in Hungary in recent years gives us hope for optimism for the future.

Supplemental material 1

Observations of migrant individuals from the Carpathian Basin in the spring period between 1898–1923.

Az 1898 és 1923 közötti tavaszi időszakban történt Kárpát-medencei vonuló példányokra vonatkozó megfigyelések

Year	Date	Location	Reference
1898	25 Apr	Selmecbánya	Schenk 1901
1899	5 May	Selmecbánya	Schenk 1901
1900	12 Apr	Selmecbánya	Vezényi 1902
1901	25 Apr	Zengg	Vezényi 1903
1901	16 Apr	Selmecbánya	Vezényi 1903
1902	18 Apr	Zengg	Vezényi 1905
1902	4 May	Selmecbánya	Vezényi 1905
1902	20 Mar	Zólyom-Lipcse	Vezényi 1905
1902	28 Mar	Libetbánya	Vezényi 1905
1903	26 Apr	Selmecbánya	Schenk 1905
1904	2 May	Selmecbánya	Schenk 1906a
1904	4 May	Dubrinics	Schenk 1906a
1905	26 Apr	Boglár	Schenk 1906b
1905	26 Apr	Nádasd	Schenk 1906b
1905	27 Apr	Türkös	Schenk 1906b
1905	11 Apr	Selmecbánya	Schenk 1906b
1906	27 Apr	Budapest	Schenk 1907
1906	23 Apr	Türkös	Schenk 1907
1906	19 Apr	Kékkő	Schenk 1907
1907	12 May	Türkös	Schenk 1908
1907	17 Apr	Oravicabánya	Schenk 1908
1907	13 Apr	Kékkő	Schenk 1908
1908	19 Apr	Tihany	Schenk 1909
1908	22 Apr	Csantavér	Schenk 1909
1908	15 May	Türkös	Schenk 1909
1908	24 Apr	Kékkő	Schenk 1909
1909	28 Apr	Nagyboldogasszony	Greschik 1910
1909	25 Apr	Lakócsa	Greschik 1910
1909	13 Apr	Arad	Greschik 1910
1909	1 May	Buttyin	Greschik 1910
1909	23 Apr	Eibenthal	Greschik 1910
1909	10 Apr	Alsóárpás	Greschik 1910
1909	18 Apr	Újradna	Greschik 1910
1909	22 Apr	Telki	Greschik 1910
1909	4 May	Nagymaros	Greschik 1910
1909	7 May	Selmecbánya	Greschik 1910
1909	15 Apr	Köblér	Greschik 1910
1909	18 Apr	Puchó	Greschik 1910
1910	11 Apr	Vasboldogasszony	Lambrecht 1911
1910	14 Apr	Nagykapornak	Lambrecht 1911
1910	5 Apr	Kismarton	Lambrecht 1911
1910	18 Apr	Dunaszekcső	Lambrecht 1911
1910	12 Apr	Buttyin	Lambrecht 1911
1910	3 May	Ungvár	Lambrecht 1911
1910	19 Apr	Eibenthal	Lambrecht 1911
1910	9 Apr	Alsóárpás	Lambrecht 1911
1910	7 Apr	Fogaras	Lambrecht 1911
1910	18 Apr	Kisberivoj	Lambrecht 1911
1910	17 Apr	Nagyberivoj	Lambrecht 1911
1910	12 Apr	Felvácza	Lambrecht 1911
1910	12 Apr	Bucsum	Lambrecht 1911
1910	12 Apr	Désakna	Lambrecht 1911

Year	Date	Location	Reference
1910	30 Apr	Mojszin	Lambrecht 1911
1910	6 Apr	Pojána Rotnuda	Lambrecht 1911
1910	25 Apr	Bodony	Lambrecht 1911
1910	5 May	Felsődiós	Lambrecht 1911
1910	25 Apr	Magasmajtény	Lambrecht 1911
1910	10 May	Alsószinevér	Lambrecht 1911
1910	4 May	Felsőapsa	Lambrecht 1911
1910	18 Apr	Vittencz	Lambrecht 1911
1910	26 Apr	Felsőbotfalu	Lambrecht 1911
1910	7 Apr	Teplicska	Lambrecht 1911
1910	5 May	Jászó	Lambrecht 1911
1910	10 May	Boroszló	Lambrecht 1911
1911	10 Apr	Vémend	Lambrecht 1912
1911	10 Apr	Vasboldogasszony	Lambrecht 1912
1911	24 Mar	Nyögér	Lambrecht 1912
1911	24 Mar	Petőfalva	Lambrecht 1912
1911	18 Apr	Csorna	Lambrecht 1912
1911	10 Apr	Temesszlatina	Lambrecht 1912
1911	30 Apr	Mohol	Lambrecht 1912
1911	27 Apr	Magyarkanizsaszállás	Lambrecht 1912
1911	30 Mar	Csererdő	Lambrecht 1912
1911	8 May	Ungvár	Lambrecht 1912
1911	26 Apr	Meszies	Lambrecht 1912
1911	27 Mar	Bruckenau	Lambrecht 1912
1911	3 May	Kereszténysziget	Lambrecht 1912
1911	25 Mar	Dezsán	Lambrecht 1912
1911	20 Apr	Sebes	Lambrecht 1912
1911	10 Apr	Detonata	Lambrecht 1912
1911	21 Mar	Székelyvarság	Lambrecht 1912
1911	20 Mar	Gyergyórékás	Lambrecht 1912
1911	4 May	Zilah	Lambrecht 1912
1911	9 Apr	Izaszacsal	Lambrecht 1912
1911	1 Apr	Majszin	Lambrecht 1912
1911	8 May	Gánya	Lambrecht 1912
1911	22 Apr	Bodony	Lambrecht 1912
1911	4 Apr	Recsk	Lambrecht 1912
1911	20 Apr	Magasmajtény	Lambrecht 1912
1911	21 Apr	Alsószinevér	Lambrecht 1912
1911	3 Apr	Pozsarova	Lambrecht 1912
1911	1 Apr	Turbaczil	Lambrecht 1912
1911	20 Mar	Jászó	Lambrecht 1912
1911	20 Apr	Boroszló	Lambrecht 1912
1911	1 Jun	Tavarna	Lambrecht 1912
1911	20 Mar	Sóslak	Lambrecht 1912
1911	22 Mar	Likavka	Lambrecht 1912
1911	12 Apr	Parasztdubova	Lambrecht 1912
1911	2 Apr	Feketekút	Lambrecht 1912
1911	28 Mar	Szentmihályfalva	Lambrecht 1912
1912	20 Mar	Rohonc	Lambrecht 1913
1912	5 Apr	Kőszegdoroszló	Lambrecht 1913
1912	12 Apr	Csorna	Lambrecht 1913
1912	12 Apr	Alsómocs	Lambrecht 1913
1912	5 Apr	Alvincz	Lambrecht 1913
1912	11 May	Felsőárpás	Lambrecht 1913
1912	16 Apr	Sebes	Lambrecht 1913
1912	22 Apr	Türkös	Lambrecht 1913
1912	25 Apr	Zám	Lambrecht 1913
1912	19 Apr	Gyergyóalfalu	Lambrecht 1913
1912	23 Apr	Izaszacsal	Lambrecht 1913
1912	20 Apr	Vámosmikola	Lambrecht 1913
1912	29 Mar	Szirák	Lambrecht 1913
1912	23 Apr	Bodony	Lambrecht 1913
1912	28 Apr	Recsk	Lambrecht 1913
1912	29 Apr	Terpes	Lambrecht 1913
1912	5 May	Felsődiós	Lambrecht 1913
1912	19 Apr	Magasmajtény	Lambrecht 1913
1912	23 Apr	Alsópalojta	Lambrecht 1913
1912	10 Apr	Znióváralja	Lambrecht 1913
1912	8 May	Felsőstubnya	Lambrecht 1913
1912	20 Mar	Liptóteplicska	Lambrecht 1913
1912	18 Apr	Boroszló	Lambrecht 1913
1912	30 Mar	Köblér	Lambrecht 1913
1912	15 Apr	Nagypásztély	Lambrecht 1913
1912	30 Apr	Zsolna	Lambrecht 1913
1912	19 Apr	Girált	Lambrecht 1913
1913	12 Apr	Visegrád	Schenk 1914

Year	Date	Location	Reference
1913	16 Apr	Szászkabánya	Schenk 1914
1913	21 Apr	Tiszafa	Schenk 1914
1913	8 May	Petrozsény	Schenk 1914
1913	30 Apr	Türkös	Schenk 1914
1913	16 Apr	Szada	Schenk 1914
1913	9 Apr	Bodony	Schenk 1914
1913	14 Apr	Znióváralja	Schenk 1914
1913	17 Apr	Garamsálfalva	Schenk 1914

Year	Date	Location	Reference
1918	2 May	Berkesd	Schenk 1919
1919	27 Mar	Pécsvárad	Schenk 1921
1920	12 Apr	Pécsvárad	Schenk 1921
1921	14 Apr	Pécsvárad	Schenk 1921
1922	7 Apr	Pécsvárad	Warga 1922
1923	11 Apr	Pécsvárad	Warga 1924
1923	22 Apr	Szekszárd	Warga 1928

References

Abhinav, C. & Dogra, P. 2020. Rufous-tailed Rock Thrush *Monticola saxatilis* at Pong Lake, Himachal Pradesh and its status in India. – Indian Birds 17(5): 135–138.

Agárdi, E. 1942. A keleti Mecsek madárvilága [The avifauna of the Eastern-Mecsek]. – Aquila 46–49: 269–299. (in Hungarian)

Anonymus 1980. Faunisztika néhány sorban [Faunistics in brief]. – Madártani Tájékoztató 4(3): 27–29. (in Hungarian)

Anonymus 1981a Faunisztika néhány sorban [Faunistics in brief]. – Madártani Tájékoztató 5(1): 20–24. (in Hungarian)

Anonymus 1981b Faunisztika néhány sorban [Faunistics in brief]. – Madártani Tájékoztató 5(2): 111–115. (in Hungarian)

Balar, R. B., Saikia, P. J., Goswami, V. P. & Kumar, S. R. P. 2016. More records of Rufous-tailed Rock Thrush *Monticola saxatilis* from southern and western India. – Indian Birds 12(4–5): 141–144.

Bársony, Gy. 1957. Madártani adatok a Bükkből [Bird observation data from the Bükk]. – Aquila 63–64: 305–306. (in Hungarian)

Bauer, H. G., Schönenberger, A. & Werth, H. 2003. Die Rückkehr des Steinrötels *Monticola saxatilis* als deutscher Brutvogel nach Bayern [The return of the Common Rock Thrush *Monticola saxatilis* as a German breeding bird to Bavaria]. – Limicola 17: 306–317. (in German)

Béldi, M. & Mannsberg, A. 1970. A Kis-Szamos vízgyűjtő területének madárvilága [The avifauna of the Kis-Szamos]. – Aquila 76–77: 165–179. (in Hungarian)

BirdLife International 2023. Species factsheet: *Monticola saxatilis*. – http://www.birdlife.org Date of access: 15. 01. 2023

Bókai, B. 1955. Madártani adatok a Pilis hegységből [Bird observation data from the Pilis Hills]. – Aquila 59–62: 410–411. (in Hungarian)

Bókai, B. 1957. Megfigyelések a kövirigók életmódjával és viselkedésével kapcsolatban [Observations on the lifestyle and habit of the Common Rock Thrush]. – Aquila 63–64: 304–305. (in Hungarian)

Chernel, I. 1899. Magyarország madarai különös tekintettel gazdasági jelentőségökre. Második könyv. – Magyar Ornithologiai Központ, Budapest, pp. 755–757.

Collar, N. 2020. Blue Rock-thrush *(Monticola solitarius)*, version 1.0. – In: del Hoyo, J., Elliott, A., Sargatal, J., Christie, D. A. & de Juana, E. (eds.) Birds of the World. – Cornell Lab of Ornithology, Ithaca, NY, USA. DOI: 10.2173/bow.burthr.01

Collar, N. & Bonan, A. 2020. Rufous-tailed Rock-thrush *(Monticola saxatilis)*, version 1.0. – In: del Hoyo, J., Elliott, A., Sargatal, J., Christie, D. A. & de Juana, E. (eds.) Birds of the World. – Cornell Lab of Ornithology, Ithaca, NY, USA. DOI: 10.2173/bow.rtrthr1.01

Csaba, J. 1963. Adatok a Dunántúl madárvilágához [Data on the avifauna of the Transdanubia]. – Aquila 69–70: 260–266. (in Hungarian)

Csörgey, T. 1905. *Monticola saxatilis*. – Aquila 12(1–4): 344. (in Hungarian)

Csörgő, T. & Gyurácz, J. 2009. Kövirigó [Common Rock Thrush]. – In: Csörgő, T., Karcza, Zs., Halmos, G., Magyar, G., Gyurácz, J., Szép, T., Bankovics, A., Schmidt, A. & Schmidt, E. (eds.) Magyar madárvonulási atlasz [Hungarian Bird Migration Atlas]. – Kossuth Kiadó Zrt., Budapest, pp. 457–458. (in Hungarian with English Summary)

Dandl, J. & Tömösváry, T. 1978. Madártani adatok a Tornai-karsztokról [Bird observational data from the Tornai-karszt]. – Madártani Tájékoztató 2(6): 20–21. (in Hungarian)

Dénes, J. 1979. Adatok a Börzsöny madárvilágához [Data on the avifauna of the Börzsöny Hills]. – Madártani Tájékoztató 3(3): 18–20. (in Hungarian)

Dobay, L. 1935. A sziklarigó, *Monticola saxatilis* L. Erdélyben [The Common Rock Thrush, *Monticola saxatilis* L. in Transylvania]. – Kócsag 8: 17–24. (in Hungarian)

Dorning, H. 1944. Megjegyzés a kövirigóról [Notes on the Common Rock Thrush]. – A Természet 40(6): 69–70. (in Hungarian)

Endes, M. 2019. Kövirigók *(Monticola saxatilis)* az Alföldön. Elemzés: okok, feltételek, kihasználás [Common Rock Thrushes *(Monticola saxatilis)* in the Great Plain of Hungary. Analysis: causes, conditions, exploitation]. – Calandrella 21–22: 83–84. (in Hungarian with English Summary)

Fântână, C., Kovács, I., Benkő, Z., Daróczi, Sz., Domșa, C. & Veres-Szászka, J. (eds.) 2021. Romanian atlas of community interest bird species. – Romanian Ornithological Society, Milvus Group Bird and Nature Protection Association, Romanian Ministry of the Environment, Waters and Forests – Biodiversity Directorate (in Romanian)

Faragó, S. 1981. Kövirigó *(Monticola saxatilis)* a Vas megyei Sághegyi Tájvédelmi Körzetben [Common Rock Thrush *(Monticola saxatilis)* in the Sághegyi Landscape Protection Area in Vas County]. – Aquila 88: 132. (in Hungarian)

Fromm, G. 1929. Vasvármegye madárvilága [The avifauna of Vas County]. – Annales Sabarienses 3: 52–69. (in Hungarian)

Gál, Sz. 2021. Kövirigó *Monticola saxatilis* [Common Rock Thrush]. – In: Szép, T., Csörgő, T., Halmos, G., Lovászi, P., Nagy, K. & Schmidt, A. (eds.) Magyarország madáratlasza [Bird Atlas of Hungary]. – Agrárminisztérium, Magyar Madártani és Természetvédelmi Egyesület, Budapest, pp. 638–639. (in Hungarian with English Summary)

Gárdonyi, G. 1958. Madártani adatok a Börzsöny hegységből [Bird observation data from the Börzsöny Mountain]. – Aquila 65: 308–309. (in Hungarian)

Grangé, J-L., Boyer, D., Gush, M. & Navarre, P. 2015. Biologie de reproduction du monticole de roche *Monticola saxatilis* dans les pyrénées occidentales françaises [Breeding biology of the Roufuos-tailed Rock-thrush *Monticola saxatilis* in the French Western Pyrenees]. – Nos Oiseaux 62: 121–140. (in French)

Greschik, J. 1910. A madárvonulás Magyarországon az 1909. év tavaszán. A Magyar kir. Ornith. Központ XVI. évi jelentése [Bird migration in Hungary in the spring of 1909. The 16th annual report of the Royal Hungarian Ornithological Centre]. – Aquila 17: 1–129. (in Hungarian)

Gyurácz, J. & Kóta, A. 2020. Vas megye madarainak névjegyzéke. Nomenclator Avium Comitatus Castriferrei in Hungaria [List of Birds of Vas County]. – Magyar Nyugat Könyvkiadó (in Hungarian with English Summary)

Habán, I. 1959. Madártani adatok a Cserhátból [Bird observational data from the Cserhát]. – Aquila 66: 289–290. (in Hungarian)

Hadarics, T. & Zalai, T. (eds.) 2008. Magyarország madarainak névjegyzéke. Nomenclator Avium Hungariae. – Magyar Madártani és Természetvédelmi Egyesület, Budapest (in Hungarian and English)

Haraszthy, L. 2015. Magyarországi tojásgyűjtemények katalógusai [Catalogue of the Hungarian Oological Collections]. – Pro Vértes Közalapítvány, Csákvár

Haraszthy, L. 2019. Kövirigó. *Monticola saxatilis* Linnaeus, 1758. [Common Rock Thrush. *Monticola saxatilis* Linnaeus, 1758.]. – Magyarország fészkelő madarainak költésbiológiája. 2. kötet. Sárgarigóféléktől a sármányfélékig (Passeriformes). – Pro Vértes Nonprofit Zrt., Csákvár, pp. 510–515. (in Hungarian)

Homoki-Nagy, I. 1980. A Börzsönyi Tájvédelmi Körzet madárvilága az 1968–1979 közötti időszak megfigyelései alapján [The avifauna of the Börzsöny Landsape Protection Area based on observational data from the period 1968–1979]. – Aquila 87: 23–25. (in Hungarian)

Keve, A. 1984. Magyarország madarainak névjegyzéke – Nomenclator Avium Hungariae. – Biológiai Tanulmányok 11. Akadémiai Kiadó, Budapest, p. 70.

Kiss, J. 1955. Szokatlan madárfészkelések [Unusual bird nestings]. – Aquila 59–62: 404. + 454. (in Hungarian and English)

Konyhás, S. 1993. Kövirigó *(Monticola saxatilis)* a Hortobágyon [Common Rock Thrush *(Monticola saxatilis)* in the Hortobágy]. – Madártani Tájékoztató 17(1): 31–32. (in Hungarian)

Konyhás, S. 2004. Kövirigó [Common Rock Thrush]. – In: Ecsedi, Z. (ed.) A Hortobágy madárvilága [Birds of the Hortobágy]. – Hortobágy Természetvédelmi Egyesület, Winter Fair, Balmazújváros – Szeged, p. 444. (in Hungarian with English Summary)

Korodi Gál, J. 1959. Adatok Kisbányahavas (Baisoara) és Bélavára (Scarisoara-Belioara) környékének madártani ismeretéhez [Data on the ornithological knowledge of the area around Baisoara and Scarisoara-Belioara]. – Aquila 66: 225–232. (in Hungarian)

Kókay, B. 2021. Kucsmás sármány [Black-headed Bunting]. – In: Szép, T., Csörgő, T., Halmos, G., Lovászi, P., Nagy, K. & Schmidt, A. (eds.) Magyarország madáratlasza [Bird Atlas of Hungary]. – Agrárminisztérium, Magyar Madártani és Természetvédelmi Egyesület, Budapest, p. 723. (in Hungarian with English Summary)

Lambrecht, K. 1911. A madárvonulás Magyarországon az 1910. év tavaszán [Bird migration in Hungary in the spring of 1910]. – Aquila 18: 9–134. (in Hungarian)

Lambrecht, K. 1912. A madárvonulás Magyarországon az 1911. év tavaszán [Bird migration in Hungary in the spring of 1911]. – Aquila 19: 43–165. (in Hungarian)

Lambrecht, K. 1913. A madárvonulás Magyarországon az 1912. év tavaszán [Bird migration in Hungary in the spring of 1912. The 19th annual report of the Royal Hungarian Ornithological Centre]. – Aquila 20: 16–145. (in Hungarian)

Magyar, G., Hadarics, T., Waliczky, Z., Schmidt, A., Nagy, T. & Bankovics, A. 1998. Magyarország madarainak névjegyzéke. Nomenclator avium Hungariae. An Annotated List of the Birds of Hungary. – KTM Természetvédelmi Hivatal Madártani Intézete – Magyar Madártani és Természetvédelmi Egyesület – Winter Fair, Budapest – Szeged

Mannsberg, A. 1918. Vonulási és előfordulási adatok Erdélyből. 1915–1917 [Migration and occurrences records from Transylvania. 1915–1917]. – Aquila 25: 13–30. (in Hungarian)

Mauks, K. 1924. *Monticola saxatilis* a diósgyőri vár romjain [*Monticola saxatilis* on the ruins of Diósgyőr Castle]. – Aquila 30–31: 297. (in Hungarian)

Mauks, K. 1928. *Monticola saxatilis*. – Aquila 34–35: 380. (in Hungarian)

Mercsák, J. L. & Mercsák, J. L. 1980. A tokaji Nagykopasz madárvilága [The avifauna of the Nagykopasz in Tokaj]. – Madártani Tájékoztató 4(1): 15–17. (in Hungarian)

Mercsák, J. L. 1980. Újból a madárpusztulásról [On bird mortality again]. – Madártani Tájékoztató 4(4): 8–9. (in Hungarian)

Mercsák, J. L. 1983 Egy kövirigó-pár *(Monticola saxatilis)* életéből [The life of a pair of Common Rock Thrush]. – Madártani Tájékoztató 7(1): 43–44. (in Hungarian)

MME NB 2013. Az MME Nomenclator Bizottság 2010. évi jelentése a Magyarországi ritka madárfajok előfordulásáról [The 2010 Annual Report of the Hungarian Checklist and Rarities Committee]. – Aquila 120: 61–73. (in Hungarian with English Summary)

MME NB 2017. Az MME Nomenclator Bizottság 2017. évi jelentése a Magyarországon ritka madárfajok előfordulásáról [The 2017 Annual Report of the Hungarian Checklist and Rarities Committee]. – Magyar Madártani és Természetvédelmi Egyesület (in Hungarian with English Summary)

MME NB 2020. Az MME Nomenclator Bizottság 2020. évi jelentése a Magyarországon ritka madárfajok előfordulásáról [The 2020 Annual Report of the Hungarian Checklist and Rarities Committee]. – Magyar Madártani és Természetvédelmi Egyesület (in Hungarian with English Summary)

Moskát, Cs. 1975. A Karancs-Medves hegység madárvilága [The avifauna of the Karancs-Medves Hills]. – Aquila 82: 105–113. (in Hungarian)

Nagy, Gy. 1955. Jegyzetek a Mátra madárvilágához [Notes on the avifauna of the Mátra]. – Aquila 59–62: 416–417. (in Hungarian)

Nagy, S. 1980. Madártani kirándulás a Tapolcai-medencében [Ornithological excursion in the Tapolca Basin]. – Madártani Tájékoztató 4(4): 15. (in Hungarian)

Pedrocchi, V. 2020. Blue Rock-thrush. – In: Keller, V., Herrando, S., Voríšek, P., Franch, M., Kipson, M., Milanesi, P., Martí, D., Anton, M., Klvanová, A., Kalyakin, M. V., Bauer, H-G. & Foppen, R. P. B. (eds.) European Breeding Bird Atlas 2. Distribution, Abundance and Change. – European Bird Census Council & Lynx Edicions, Barcelona, pp. 746–747.

Péterfay, J. 1957. Madártani adatok a Mecsek északi oldaláról [Observation data from the northern part of the Mecsek]. – Aquila 63–64: 306. (in Hungarian)

Radetzky, D. 1919. Adalékok Pécs város madárvilágához [Additional data to the avifauna of Pécs]. – Aquila 26: 112–113. + 135. (in Hungarian and German)

Radetzky, D. 1979. Adatok a Velencei-hegység madárvilágához [Data on the avifauna of the Velence Hills]. – Madártani Tájékoztató 3(3): 29–30. (in Hungarian)

Réthy, Zs. (ed.) 1980. Magyar madártani bibliográfia. Bibliographia Ornithologica Hungarica [Hungarian Ornithological Bibliography]. – Békés m. Tanács VB Környezet és Természetvédelmi Bizottsága, Békéscsaba (in Hungarian)

Sághy, A. 1955. Adatok a Gerecse-hegység és a Középső-Duna madárvilágához [Data on the avifauna of the Gerecse and the Central Danube]. – Aquila 59–62: 191–200. (in Hungarian)

Sághy, A. 1968. Néhány adat a Gerecse-hegység ritkább madarairól [Some data on the rare bird species of the Gerecse]. – Aquila 75: 273–279. (in Hungarian)

Schenk, J. 1901. A madárvonulás Magyarországon 1899. tavaszán. A Magyar Ornithologiai Központ VI. éves jelentése [Bird migration in Hungary in the spring of 1899. The 6th annual report of the Hungarian Ornithological Centre]. – Aquila 8: 50–122. (in Hungarian)

Schenk, J. 1905. A madárvonulás Magyarországon 1903. tavaszán. A Magyar Ornithologiai Központ X. éves jelentése [Bird migration in Hungary in the spring of 1903. The 10th annual report of the Hungarian Ornithological Centre]. – Aquila 12: 83–202. (in Hungarian)

Schenk, J. 1906a A madárvonulás Magyarországon az 1904. év tavaszán. A Magyar Ornithologiai Központ XI. évi jelentése [Bird migration in Hungary in the spring of 1904. The 11th annual report of the Hungarian Ornithological Centre]. – Aquila 13: 9–66. (in Hungarian)

Schenk, J. 1906b A madárvonulás Magyarországon az 1905. év tavaszán. A Magyar Ornithologiai Központ XII. évi jelentése [Bird migration in Hungary in the spring of 1905. The 12th annual report of the Hungarian Ornithological Centre]. – Aquila 13: 9–66. (in Hungarian)

Schenk, J. 1907. A madárvonulás Magyarországon az 1906. év tavaszán. A Magyar Ornithologiai Központ XIII. évi jelentése [Bird migration in Hungary in the spring of 1906. The 13th annual report of the Hungarian Ornithological Centre]. – Aquila 14: 1–119. (in Hungarian)

Schenk, J. 1908. A madárvonulás Magyarországon az 1907. év tavaszán. A Magyar Ornithologiai Központ XIV. évi jelentése [Bird migration in Hungary in the spring of 1907. The 14th annual report of the Hungarian Ornithological Centre]. – Aquila 15: 1–152. (in Hungarian)

Schenk, J. 1909. A madárvonulás Magyarországon az 1908. év tavaszán. A Magyar kir. Ornithologiai Központ XV. évi jelentése [Bird migration in Hungary in the spring of 1908. The 15th annual report of the Hungarian Ornithological Centre]. – Aquila 16: 1–128. (in Hungarian)

Schenk, J. 1914. A madárvonulás Magyarországon az 1913. év tavaszán. A Magyar Királyi Ornithologiai Központ XX. évi jelentése [Bird migration in Hungary in the spring of 1913. The 20th annual report of the Hungarian Ornithological Centre]. – Aquila 21: 137–187. (in Hungarian)

Schenk, J. 1916. Régi híres madárgyűjtemények [Old famous bird collections]. – Aquila 23: 163–195. (in Hungarian)

Schenk, J. 1919. Madárvonulási adatok Magyarországból. II. [Bird migration data from Hungary. II.]. – Aquila 26: 46–75. (in Hungarian)

Schenk, J. 1920. Erdély madarai. Zeyk Miklós hátrahagyott kézirata [Birds of Transylvania. Manuscript left behind by Miklós Zeyk]. – Aquila 27: 71–243. (in Hungarian)

Schenk, J. 1921. Madárvonulási adatok Magyarországból. IV. [Bird migration data from Hungary. IV.]. – Aquila 28: 97–126. (in Hungarian)

Schmidt, E. 1972a Adatok a Badacsonyi Tájvédelmi Körzet madárfaunájához [Data on the avifauna of the Badacsony Landscape Protection Area]. – Aquila 78–79: 81–91. (in Hungarian)

Schmidt, E. 1972b Madártani megfigyelések Budaörsön [Ornithological observations in Budaörs]. – Állattani Közlemények 59: 183–184. (in Hungarian)

Schmidt, E. 1976. Faunisztikai jegyzetek 3 [Faunistical notes 3]. – Aquila 83: 295–296. (in Hungarian)

Schmidt, E. 1980. Állományváltozások [Population changes]. – Madártani Tájékoztató 4(4): 30–32. (in Hungarian)

Schmidt, E. 1994. Budaörsi helyzetkép [Situation in Budaörs]. – Madártávlat 1(6): 7–9. (in Hungarian)

Schmidt, E. 1995. A hónap madara: a kövirigó [Birds of the month: Common Rock Thrush]. – Madártávlat 2(5): 6–7. (in Hungarian)

Schmidt, E. 2000. Kövirigó *Monticola saxatilis* [Common Rock Thrush. *Monticola saxatilis*]. – In: Haraszthy, L. (ed.) Magyarország madarai. Második, javított kiadás [Bird of Hungary. Second, improved edition]. – Mezőgazda Kiadó, Budapest, pp. 286–287. (in Hungarian)

Shirihai, H. & Svensson, L. 2018. Handbook of the Western Palearctic birds. Vol. 1. – Christopher Helm, London, pp. 273–275.

Simig, L. 1978. Kiegészítő adatok a Budapesti Sas-hegy természetvédelmi terület madár faunájához [Additional data to the avifauna of the Sas-hegy Nature Protection Area in Budapest]. – Madártani Tájékoztató 2(2): 5–8. (in Hungarian)

Szeőts, B. 1922. Tavarna és vidékének madarai [The avifauna of Tavarna and its surroundings]. – Aquila 29: 132–143. (in Hungarian)

Szombath, L. 1944. A kövirigó: *Monticola saxatilis* L. [The Common Rock Thrush: *Monticola saxatilis* L.]. – A Természet 40: 45–46. (in Hungarian)

Tarján, T. 1930. Békéscsaba és vidékének madárvilága [The avifauna of Békéscsaba and its surroundings]. – In: Korniss, G. (ed.) Békéscsaba. Történelmi és kulturális monográfia [Békéscsaba. Historical and cultural monography]. – Körösvidék Nyomdája, Békéscsaba, pp. 103–129. (in Hungarian)

Turcek, F. 1942. Adatok Nyitra madárvilágához [Data on the avifauna of Nyitra]. – Aquila 46–49: 300–302. (in Hungarian)

Turcek, F. J. 1959. Madármegfigyelések a Szitnyán [Bird observations in the Szitnya]. – Aquila 66: 288–289. (in Hungarian)

Varga, F. 1980. Természetvédelmi terület erdei énekesmadarak számára a Medves hegységben [Nature protection area for forest dwelling Passerines in the Medve Hills]. – Madártani Tájékoztató 4(2): 30–31. (in Hungarian)

Varga, F. 1984. Szajkó *(Garrulus glandarius)* nagyarányú állománynövekedése a Zagyva forrásvidékén [Large-scale population increase of the Eurasian Jay *(Garrulus glandarius)* in the Zagyva headwaters]. – Madártani Tájékoztató 8(2): 101–102. (in Hungarian)

Vezényi, Á. 1902. madárvonulás Magyarországon az 1900. év tavaszán. A Magyar Ornithologiai Központ VII. évi jelentése [Bird migration in Hungary in the spring of 1900. The 7th annual report of the Hungarian Ornithological Centre]. – Aquila 9: 81–155. (in Hungarian)

Vezényi, Á. 1903. A madárvonulás Magyarországon az 1901. év tavaszán. A Magyar Ornithologiai Központ VIII. évi jelentése [Bird migration in Hungary in the spring of 1901. The 8th annual report of the Hungarian Ornithological Centre]. – Aquila 10: 104–187. (in Hungarian)

Vezényi, Á. 1905. A madárvonulás Magyarországon az 1902. év tavaszán. A Magyar Ornithologiai Központ IX. évi jelentése [Bird migration in Hungary in the spring of 1902. The 9th annual report of the Hungarian Ornithological Centre]. – Aquila 12: 1–77. (in Hungarian)

Volet, B. & Keller, V. 2020. Rufous-tailed Rock-thrush. – In: Keller, V., Herrando, S., Voríšek, P., Franch, M., Kipson, M., Milanesi, P., Martí, D., Anton, M., Klvanová, A., Kalyakin, M. V., Bauer, H-G. & Foppen, R. P. B. (eds.) European Breeding Bird Atlas 2. Distribution, Abundance and Change. – European Bird Census Council & Lynx Edicions, Barcelona, pp. 744–745.

Warga, K. 1922. Madárvonulási adatok Magyarországból [Bird migration data from Hungary]. – Aquila 29: 91–131. (in Hungarian)

Warga, K. 1924. Madárvonulási adatok Magyarországból [Bird migration data from Hungary]. – Aquila 30–31: 179–237. (in Hungarian)

Warga, K. 1928. Madárvonulási adatok Magyarországból [Bird migration data from Hungary]. – Aquila 34–35: 257–305. (in Hungarian)

Ornis Hungarica 2023. 31(1): 163–171.
DOI: 10.2478/orhu-2023-0011

Four nesting attempts of a Great Bustard *Otis tarda* female in one reproductive season

Dénes Nagy[1]*, Zsuzsanna Kurucz[1], Péter Tóth[1], Rainer Raab[2] & Attila Králl[1]

Received: January 23, 2022 – Revised: April 24, 2023 – Accepted: April 25, 2023

Nagy, D., Kurucz, Zs., Tóth, P., Raab, R. & Králl, A. 2023. Four nesting attempts of a Great Bustard *Otis tarda* female in one reproductive season. – Ornis Hungarica 31(1): 163–171. DOI: 10.2478/orhu-2023-0011

Abstract A mature Great Bustard *(Otis tarda)* female tagged with a satellite transmitter in Dévaványa made four breeding attempts in 2019. A total of seven eggs were laid on the four occasions. None of the breeding attempts were successful, and the bird was killed by a predator, presumably a Red Fox *(Vulpes vulpes)*, during the fourth breeding attempt. The four egg-laying attempts are a new experience in the reproductive biology of the species. The failure of the nestings and the death of the bird itself confirm that the conservation measures of the species, as emphasised in international and national conservation plans – controlling predators and egg predator populations, ensuring undisturbed breeding conditions – are important conservation biology actions serving for the protection of the species.

Keywords: satellite tracking, reproductive biology, Great Bustard, *Otis tarda*, conservation biology

Összefoglalás Egy Dévaványán műholdas jeladóval jelölt, ivarérett túzoktojó 2019-ben négy alkalommal próbálkozott költéssel, ezalatt összesen hét tojást rakott. Egyik költés sem volt sikeres, sőt a madarat a negyedik költés alatt ragadozó, feltehetően vörö róka zsákmányolta. A négy tojásrakási próbálkozás új fejlemény a faj költésbiológiáját illetően. A költések tönkremenetele és a madár pusztulása megerősíti, hogy a faj védelmének nemzetközi és hazai tervekben rögzített természetvédelmi céljai – ragadozók és tojáspredátorok állományszabályozása, költési feltételek zavartalanságának biztosítása – fontos konzervációbiológiai teendők a faj megőrzése érdekében.

Kulcsszavak: műholdas jeladó, költésbiológia, túzok, *Otis tarda*, konzervációbiológia

[1]*BirdLife Hungary/MME (Magyar Madártani és Természetvédelmi Egyesület), 1121 Budapest, Költő utca 21., Hungary*
[2]*TB Raab Ltd., Deutsch-Wagram, Austria*
**corresponding author, e-mail: nagy.denes@mme.hu*

Introduction

The Great Bustard *(Otis tarda)* is a strictly protected (MME 2022), globally threatened (BirdLife International 2017), vulnerable species in Hungary. Globally, its population is stable with a slight increase observed only in the Iberian Peninsula and the Carpathian Basin (Alonso 2014). Its population in Hungary has stabilised and started to increase slightly after a decline until the 1980s, owing to conservation programmes (Alonso 2014, Czifrák 2014). In the Hungarian context, its reporoductive biology (Faragó 1992, Demeter *et al.* 1994, Janó & Végvári 2016, Haraszthy 2019) was described as females having nests with 1–3 eggs (2 eggs being the most typical), and the literature also mentions that it may have a

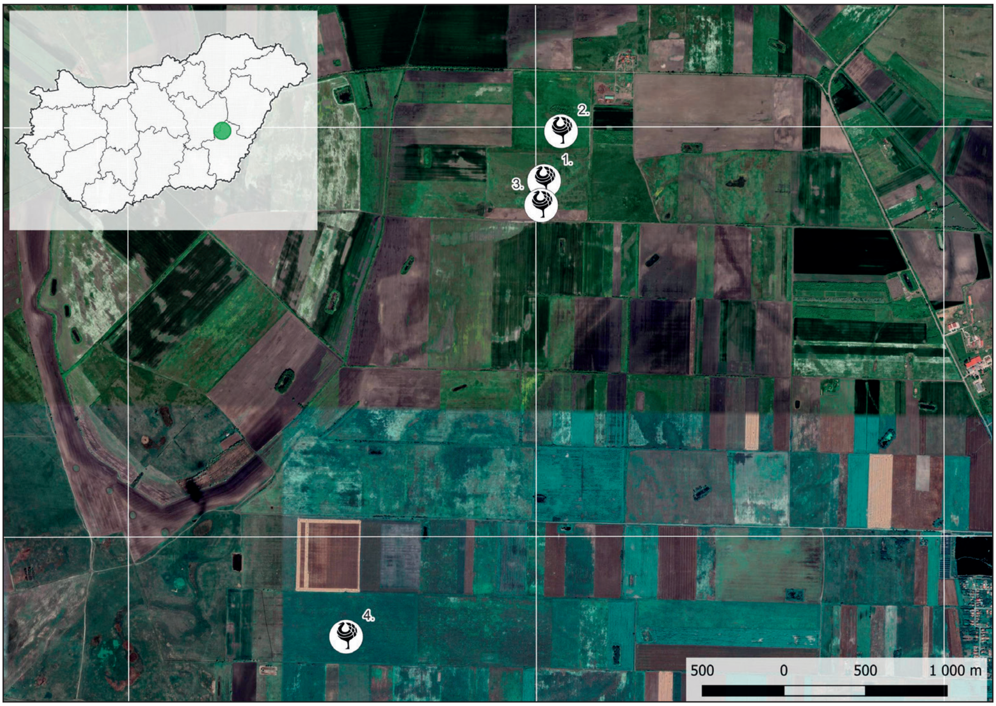


Figure 1. Overview map of the nesting attempts, see *Table 1*
1. ábra A fészkelési próbálkozások áttekintő térképe, lásd *1. táblázat*

Table 1. Basic data of the nesting attempts
1. táblázat A fészkelési próbálkozások alapadatai

Nesting attempts	Period	Laid eggs	Incubation time	Cause of failed nesting	Remark
1.	20.04.–25.04.	3	1–5 days	probably too many Roe Deers on the plot	faeces contamination
2.	02.05.–06.05.	2	3–6 days	probably too many Roe Deers on the plot	faeces contamination
3.	15.05.–28.05.	1	13 days	disturbance of an egg predator	egg predation
4.	04.06.–21.06.	1	14–17 days	most probably Red Fox predation	egg predation

second hatch or replacement nest, i.e. it may start a second nesting when its first nest failed, had been destroyed or abandoned. Previous studies based on rescued eggs (Németh *et al.* 2009), indicate that replacement nesting can be significantly prolonged, with up to four local nesting peaks in a year, but this could not be linked to individual bird behaviour, and it was questioned whether this pattern had a population, behavioural, autecological or weather-related background. Note that the study of rescued eggs also indicates that the nesting site is typically a site under some kind of agricultural management or other human activity that hinders the nesting female bird to incubate the nest, and thus, the egg must be rescued

(Demeter *et al.* 1994, Janó & Végvári 2016). The study of satellite tracked Great Bustards eliminates this factor, ideally also providing information from individuals that choose plant cultures, free from human disturbance, as nesting sites.

According to the Hungarian Great Bustard Species Conservation Plan (Faragó 2004) and Hungarian conservation studies (Vadász & Lóránt 2014), it is of key importance to preserve older, experienced female Great Bustards, and thus, increase the success rate of nesting, which is key to the conservation of the species in the context of the relatively low reproduction rate.

BirdLife Hungary/MME has been carrying out satellite tracking of Great Bustards in the framework of the LIFE Nature project „Cross-border conservation of Great Bustards in Central Europe", LIFE15 NAT/AT/000834, under the conservation authority permit PE-KTF/5218-16/2017, also in cooperation with National Park Directorates. The aim of the action was, among others, to identify the ecological factors that can be influenced by conservation measures affecting the Great Bustard population, in particular the land use of old females, their nesting behaviour and identifying the reasons for the loss of these experienced birds, which are important for the population (Alonso *et al.* 2004).

Previously, a single GPS transmitter was installed on Hungarian Great Bustard (Lóránt 2018). Within the framework of the above mentioned project, one mature female was equipped with a GPS transmitter (Ecotone) in March 2018, and a total of 16 wild birds (2 mature females, 14 chicks, respectively) until spring 2021. Besides, 6 repatriated chicks (from rescued eggs) received satellite transmitters by then.

Several instances of breeding or breeding attempts by the tagged old females and matured, tagged female chicks were detected.

Prior to our work, data collection and analysis of Great Bustard populations by satellite (radiotransmitter) tracking has been carried out on a large scale in Spain (Martin *et al*. 2007, Alonso 2008). Based on their experience, in addition to monitoring individual behaviour, population parameters and habitat use can be investigated. We started our studies with similar ambitions for tagging birds in our country. The Spanish research mainly analysed the survival of chicks, based on the number of chicks that already accompanied the female. There were no publications on nesting.

The present paper is a by-product of the study, while the project plans to adopt the data from tracked birds into a similar habitat suitability model described by Spanish Great Bustard conservation and research community (Suárez-Seoane *et al.* 2002), apart from the above mentioned aims. This model is expected to improve the overall nature conservation efforts on different Great Bustard habitats, and future habitats suitable for the hopefully expanding population in Hungary.

Materials and Methods

On 14 July 2018, an Ornitela GPS transmitter was placed on an mature Great Bustard female at the Great Bustard Rescue Centre in Dévaványa, in cooperation with the staff of the Körös-Maros National Park Directorate (KMNPD). The Ornitela transmitter type is OrniTrack50, a

50 g device with GSM based communication and solar charging. The data of the transmitter can be followed online via the basic geoinformatics interface with graphs of the transmitter sensor data available on the manufacturer's website, or the partial or complete data set can be downloaded and analysed in GIS software. When the transmitter was mounted, a flexible harness was attached to the ears on the transmitter housing, and two strands of this harness were threaded across the bird's chest, with a tension such that the harness could track the bird's changes in condition (including growth in the case of chicks) without hindering its movement or behaviour (Alonso 2008). A soft neoprene sheet was attached under the transmitter housing, cushioned against the bird's body.

The transmitter was set to optimise battery charge. During the breeding period, the transmitter attempted to connect to the GSM network and transmit data every 3 h, recording GPS points at a minimum of every 4 h depending on battery charge, but typically of every 5 min at maximum battery charge and every half hour below 50% battery charge.

We have monitored the behaviour and movements of the marked birds on a daily basis, and when needed, we communicated with the staff of the National Park Directorate responsible for the area where the bird was to be found. The data collected from the satellite tracking during the project will be used and evaluated for modelling the species' land use, which will underpin conservation management.

In this paper, we summarise our experience from the raw data of this tagged bird and related field studies for a given breeding period.

Results

According to the data from the tagged bird, the begining of the year 2019 until the breeding season was characterised by movements from wintering sites towards male displaying sites (leks), while it also occasionally used potential nesting areas, as if probing their quality.

On 19th April 2019 it stayed several times in the immediate vicinity of the point that was later identified as its first nest for short periods of time and on 20th April 2019, she started to spend increasingly longer periods of time there. This area was an uncultivated fallow field. We documented clear breeding behaviour for the first time on 24th April, when it seemed certain that the bird had started nesting: successive points marked a specific location, and the accelerometer showed a smaller variation than normal daily activity patterns. The bird, although it made quite a lot of comfort movements almost through the whole day, sometimes even leaving the nest for slightly longer periods overnight, presumably most often was under cover of vegetation as its battery charge began to decrease. On 25th April, in the early hours of the morning, the bird left the nest and did not return for several hours. KMNPD staff went to the area and found the nest with three eggs. The eggs and the nest were heavily contaminated with bustard faeces and it was certain that the female would not return to it. The eggs were collected and transported to the Great Bustard Rescue Centre to hatch by the conservation officers. Meanwhile, according to the transmitter, the bird was moving around nearby on adjacent fields, but was not observed. The fallow land, where the nest was abandoned, was used by several Roe Deer *(Capreolus capreolus)*.

The bird stayed nearby until the next nesting attempt, she used more open areas evidenced by the charging of the transmitters's battery. She did not return to the exact location of her former nest, but visited nearby a few times.

On 1st May 2019, the bird first started to give GPS locations at its second nesting site in a few point recordings. This site was an agricultural area adjacent to the previous nest location. The nesting was detected on 2nd May, based on movement changes described above. The nest was about 330 m far from the previous one. The bird spent much more time on the nest than the first time, less comfort movements were observed, and it travelled shorter distances. On 6th May, in the early morning hours, the bird left the nest and did not return until midday, when the conservation officers visited the nest and found two eggs heavily contaminated with faeces, meaning that it was certain that the bird would not return to the nest. Meanwhile, the female that had left the nest was again not observed, but recorded points showed that it had used the same nearby agricultural land as after the first failed nesting, and returned to its first nest site briefly at noon the following day.

On the same day, 6th May in the afternoon, there was a major movement in the direction where the bird later started its fourth nesting (see below). The female then returned the next day, on 7th May, to the same area where its first two nesting attempts had taken place. On 11th May, at dawn, she repeated this behaviour moving to more southerly areas, did not return further north, but moved to the east of the Dévaványa-Ecsegfalva road, south of the 400 ha fenced Great Bustard Protection Area, which also functions as a prolonged displaying site during this period (probably looked for males). From there the bird returned to the western side of the road on 13th May. From 14th May onwards, she used the same fallow land continuously where its first breeding failed. She visited the location of its first nest once for a short period.

On the afternoon of 15th May, the female first visited the site that was later identified as its third nesting site, staying overnight, but the next day, 16th May, it moved around the area only. On 18th May, she was observed to start its third nesting, staying at this point for short periods, but returning regularly. During the nesting period she moved less, compared to the previous attempts, its comfort movements were short in space and time. Meanwhile, contrary to expectations, the battery of the transmitter did not decrease, as the solar panel was able to recharge compared to the first breeding attempt on the same patch, presumably because the bird chose lower, less overcast vegetation as a nesting site. On the previous day, the points obtained were not always from the nest itself, within a few metres of it, but this was not to be considered of major importance due to the shading of the vegetation that had grown up fast in the wet weather. On 28th May, the bird was observed to have left the nest in late morning, not returning back, and its accelerometer showed a different, restless pattern, although the female did not show any major movements. Conservation officers who arrived on the scene in the afternoon found the nest in the edge of a damp patch of the fallow land, with no eggs, only the imprint of one egg in the soft soil. No eggshells were found, presumably because of nest predation, but no other evidence of a predator was observed. No sightings of the bird were made, the transmitter data indicating that she remained on the agriculture plot at this time.

The bird stayed on and near this fallow land for the next two days, 29–30 May, once visiting the area around the first nest. At noon on 30th May, after the bird flew a distance of about 2 km, it arrived to the previously visited southern area, where it used a rather small plot until 2nd June. The bird repeated this with another nearby plot, and then on 3rd June, it visited the fallow land where it had its first and third nests, from where it again flew to the southern area. On these days, its accelerometer showed more pronounced activity.

The female first touched the point that turned out to be its fourth nest on 4th June. On 10th June it was observed that the bird started nesting again, when its points came clearly from one place, although in the days before it had been moving in a small area, in the immediate vicinity of the future nest, and did not move away from it. The GPS signals could not pinpoint the nest so clearly, presumably due to the higher and denser vegetation the signal was not accurate. The bird's transmitter recorded several accelerometer peaks during the nesting, which was unusual compared to the three previous nesting occasions. The bird usually left the nest for a short period at dawn, sometimes for a greater distance than on the longer third nesting. On the morning of 20th June, it made a slightly longer circuit south of the nest, but returned. On 22nd June, the 15th–18th day of the incubation, we noted that the transmitter data showed an unusual pattern, something had happened to the bird (accelerometer showed transmitter turning over, then sudden movements, temperature data drop) in the afternoon of 21st June. Around noon on 22nd June, KMNPD conservation officers first scanned the area with a drone (it was possible that the transmitter harness had broken – but the drone could not detect the cause of the strange signals) and then went to the nest location in person. The remains of the bird were found near the nest, 3 metres away, most probably surprised by a predator, presumably a Red Fox *(Vulpes vulpes)*, on the nest. There were no eggs in the nest, but at least one egg imprint was observed. The egg was either taken by the predator that killed the hatching female, or by another nest predator, no egg remains were found. The transmitter harness was chewed through in three places, and the transmitter itself showed minor tooth marks.

Discussion

Main findings on the nesting of the tagged bird:

- For the first time ever, a Great Bustard was recorded trying to nest four times in one year. Data from a previous Hungarian study (Németh *et al*. 2009) based on age determination of rescued eggs suggested that this was possible, but this is the first data at the individual level to support this.
- In this year, the number of laid eggs presumed from direct and indirect evidence for this female was 7 in total. Studies carried out on a larger scale in Spain (Morales *et al*. 2002) have shown that the average Great Bustard female in Spain has a productivity of 0.14 ± 0.09 chicks per year, and the high number of eggs produced in one breeding period suggests a significant energy investment in case of this Pannonian individual.
- The Great Bustard is very sensitive to disturbance, as evidenced by the nesting attempts of this specimen. It is not known what caused exactly the abandonment of the nests, except for the fourth nesting attempt, but some disturbance is suspected, as indicated by the presence of nests contaminated with faeces of the bird. Experience has shown

that nesting birds contaminate the nest when they are suddenly forced to do so by some drastic disturbance and do not return (Szél, pers. comm.). This rules out the possibility that the nest was abandoned because of a possible infertility of the eggs or because of unfavourable weather or biological conditions for the subsequent fostering of chicks. For the first and third nests, the bird used a field that was not cultivated by the farmer that year, so no significant human disturbance can be assumed, and started the second nest in a field adjacent to the first with similar conditions. There were quite a large number of Roe Deer on these fields, presumably due to lack of disturbance, and the bird may have been disturbed by the continuous movement of larger animals near the nest at night. On arable lands and grasslands affected by agricultural works, farming operations may cause more significant disturbance to the nesting female bustard (Németh *et al*. 2009, Janó & Végvári 2016).

– Although the bird was already a mature female when the transmitter was placed, so she must have been an experienced specimen, she used a total of only two narrow nesting locations in this period. She used the surroundings of the first site three times in succession, despite the fact that each time her nesting could have been disturbed by some external, possibly non-human factor. The fourth nesting site was visited several times during the year, but only the fourth time did the bird decide to nest there. The literature mentions that females have a preference for certain locations (Alonso *et al.* 2000), and this was also demonstrated by this individual during the first three nesting attempts, too.

– The predation on nesting females as a threat factor described in the national (Faragó 2004) and international conservation plans (Nagy 2009) has been confirmed this case, highlighting the need for predator management in Great Bustard habitats. It should be noted that predator management in this area of the KMNPD is also carried out within the framework of the LIFE project to protect the Great Bustard by hunting methods [monitoring of Red Fox, Badger *(Meles meles)*, Golden Jackal *(Canis aureus)* and Wild Boar *(Sus scrofa)* populations, burrow hunting and trapping as necessary, preferably before the reproduction season of the predator species, and trying to maintain a target number zero for Wild Boar].

– Also confirmed the presence of negative nest predation pressure on breeding success. Of the 7 eggs laid, at least one most probably have been consumed by a nest predator, but it is also possible that even the egg predator discovering the nest could have caused the female to leave the nest. Predator management using the above-mentioned hunting methods also includes population control of nest predators (Hooded Crow *Corvus cornix*, and Magpie *Pica pica*) control with live-catching traps.

All in all, the unique fate of this female Great Bustard underline the relevance of efforts that have characterised conservation work so far. The loss of experienced females will reduce the already low population growth potential. Based on this case study, the need to integrate predator and egg predator population control into game management is of paramount importance in Great Bustard habitats, but from a game management perspective, the need for Roe Deer management around typical nesting sites may also arise. An important lesson is that nesting bustards could invest considerable energy in egg laying, more than previously thought, and that conservation efforts could achieve more significant results by increasing the success rate of the first nest. In the case of agricultural support schemes in Great Bustard habitats, it would be advisable to implement measures of as little disturbance as possible at the beginning of the nesting season (late March–May), and preferably to exclude all agricultural work in Great Bustard nesting sites. Detection of such nesting sites as early as possible, preferably by remote sensing, could be an important conservation objective for the species.

Acknowledgements

We thank the EU LIFE fund for the support („Cross-border conservation of the Great Bustard in Central Europe", LIFE15 NAT/AT/000834) and to all project partners and colleagues implementing the project. We thank Miklós Lóránt and Ákos Németh for the help in the tagging activity, the editor and anonymous reviewers for their comments. Special thanks to the staff of KMNPD (Gizella Janó, Antal Szél and their colleagues) for the smooth implementation of the field work and for sharing their field experience.

References

Alonso, J. C., Morales, M. B. & Alonso, J. A. 2000. Partial migration, and lek and nesting area fidelity in female Great Bustards. – The Condor 102(1): 127–136. DOI: 10.1093/condor/102.1.127

Alonso, J. C., Martín, C. A., Alonso, J. A., Palacín, C., Magaña, M. & Lane, S. J. 2004. Distribution dynamics of a Great Bustard metapopulation throughout a decade: influence of conspecific attraction and recruitment. – Biodiversity and Conservation 13: 1659–2004. DOI: 10.1023/B:BIOC.0000029329.44373.47.

Alonso, J. C. 2008. Guidelines for capturing and radio-tracking Great Bustards. – Prepared for the CMS Memorandum of Understanding on the Conservation and Management of the Middle European Population of Great Bustard. BirdLife International, Brussels

Alonso, J. C. 2014. The Great Bustard: past, present and future of a globally threatened species. – Ornis Hungarica 22(2): 1–13. DOI: 10.2478/orhu-2014-0014

BirdLife International 2017. *Otis tarda*. The IUCN Red List of Threatened Species 2017: e.T22691900A119044104. –DOI: 10.2305/IUCN.UK.2017-3.RLTS.T22691900A119044104.en.

Czifrák, G. 2014. Practice of incubation, rearing and repatriation at the Great Bustard Rescue Station of the Körös-Maros National Park Directorate. – Aquila 121: 133–136.

Demeter, L., Fatér, I. & Szép, T. 1994. The degree and cause of destruction of endangered Great Bustard *(Otis tarda)* nests in Hungarian populations. – Ornis Hungarica 4: 19–24.

Faragó, S. 1992. Clutch size of the Great Bustard *(Otis tarda)* in Hungary. – Aquila 99: 69–84.

Faragó, S. 2004. Species conservation plan for Great Bustard *(Otis tarda)*. – Office for Nature Conservation, Ministry of Environment and Water, Budapest

Haraszthy, L. 2019. Magyarország fészkelő madarainak költésbiológiája. I–II. kötet [Breeding Biology of the Hungarian Birds. Vol. I–II.]. – Pro Vértes Nonprofit Zrt. (in Hungarian)

Janó, G. & Végvári, Zs. 2016. Nest site selection of the Great Bustard *(Otis tarda)* in Körös-Maros National Park, Eastern Hungary. – Ornis Hungarica 24(2): 32–45. DOI: 10.1515/orhu-2016-0013

Lóránt, M. 2018. Túzokok után kapkodnak a sasok [Aquilae captant Great Bustard]. – Két víz köze 2018 ősz, KNPI Hírlevele: 4–5. (in Hungarian)

Magyar Madártani és Természetvédelmi Egyesület (MME) 2022. Magyarország madarai: Túzok [Birds of Hungary: Great Bustard]. – http://www.mme.hu/magyarorszagmadarai/madaradatbazis-otitar (in Hungarian)

Martin, C. A., Alonso, J. C., Alonso, J. A., Palacín, C., Magana, M. & Martin, B. 2007. Sex-biased juvenile survival in a bird with extreme size dimorphism, the Great Bustard *Otis tarda*. – Journal of Avian Biology 38(3): 335–346. DOI: 10.1111/j.2007.0908-8857.03811.x

Morales, M. B., Alonso, J. C. & Alonso, J. A. 2002. Annual productivity and individual female reproductive success in a Great Bustard *Otis tarda* population. – The Ibis 144(2): 293–300. DOI: 10.1046/j.1474-919X.2002.00042.x

Nagy, Sz. 2009. International single species action plan for the Western Palearctic population of Great Bustard, *Otis tarda tarda*. – BirdLife International on behalf of the European Commission

Németh, Á., Lóránt, M. & Vadász, Cs. 2009. Mennyire tekinthető hatékonynak az Agrár-Környezetgazdálkodási Program túzokvédelmi célprogramjaiban szereplő előírások? [How effective are the management regulations of the Great Bustard Protection Agro-Environmental Program?]. – Természetvédelmi Közlemények 15: 226–234. (in Hungarian with English Summary)

Suárez-Seoane, S., Osborne, P. E. & Alonso, J. C. 2002. Large-scale habitat selection by agricultural steppe birds in Spain: identifying species–habitat responses using generalized additive models. – Journal of Applied Ecology 39(5): 755–771. DOI: 10.1046/j.1365-2664.2002.00751.x

Vadász, Cs. & Lóránt, M. 2014. Key mortality causes of the Great Bustard *(Otis tarda)* in Central Hungary: an analysis of known fatalities. – Ornis Hungarica 22(2): 32–41. DOI: 10.2478/orhu-2014-0016

Ornis Hungarica 2023. 31(1): 172–196.
DOI: 10.2478/orhu-2023-0012

Observations of birds of prey in Eastern Nimba Nature Reserve, Liberia between 2015 and 2017

Mátyás Prommer

Received: December 22, 2022 – Revised: May 05, 2023 – Accepted: May 08, 2023

Prommer, M. 2023. Observations of birds of prey in Eastern Nimba Nature Reserve, Liberia between 2015 and 2017. – Ornis Hungarica 31(1): 172–196. DOI: 10.2478/orhu-2023-0012

Abstract Distribution and biology of birds of prey species have been well-documented in most parts of the globe. Knowledge gaps are continuously shrinking due to more research, new technologies and increasing possibilities to reach remote areas. However, there are still some regions where data on birds of prey are scarce due to various reasons. Some parts of West Africa are such places, mostly because civil wars and the outbreak of Ebola prevented any kind of research. In the period 2015–2017, a butterfly research project in Nimba Mountains, Liberia offered opportunity to collect data also on birds of prey species. This article aims to provide a comprehensive list of birds of prey species in the area and compare it to other available historic and recent lists. In the frame of the project, 20 species were recorded. The results of comparing historic and recent records show that species of dry open habitats appeared and even settled in Nimba Mountains' predominantly rainforest habitat. That suggests a habitat shift likely due to both climate change and human land transformation activities.

Keywords: Liberia, Nimba Mountains, birds of prey, Eastern Nimba Nature Reserve

Összefoglalás A ragadozómadár-fajok elterjedése és biológiája a Föld nagy részén már jól dokumentált. A kutatásoknak, új technikáknak és a távoli területek egyre egyszerűbb elérhetőségének köszönhetően folyamatosan nő az ismeretanyag. Vannak azonban olyan területek, ahonnan különböző okok miatt még kevés adatunk van a ragadozómadarakról. Nyugat-Afrika egyes vidékei ilyen területek, mivel a polgárháborúk és az Ebola járvány kitörése megakadályozták a kutatásokat. 2015–2017 között egy – a libériai Nimba-hegységben zajló – lepkékre irányuló kutatás lehetővé tette, hogy a ragadozómadár-fajokról is gyűjtsünk információkat. Jelen cikk célja, hogy egy átfogó képet adjon a területen előforduló ragadozómadár-fajokról és összehasonlítsa a korábbi és recens fajlistákat. A projektben összesen húsz fajt figyeltünk meg. A korábbi és jelen adatsorok összehasonlítása azt mutatja, hogy a Nimba-hegység elsődlegesen esőerdei élőhelyein megjelentek, sőt meg is telepedtek a száraz, nyílt területeket kedvelő fajok. Ez valószínűleg az élőhelyek átalakulását jelzi, amelynek okai feltehetően az éghajlatváltozás és az ember tájátalakító tevékenysége.

Kulcsszavak: Libéria, Nimba-hegység, ragadozómadár, Kelet-Nimba Természetvédelmi Terület

Mátyás Prommer, Madárvilág Nonprofit Kft., 2500 Esztergom, Béke tér 58., Hungary,
e-mail: mprommer@gmail.com

Introduction

Despite the continuous development of technologies and increasing accessibility of remote places by researchers and tourists, there are still places to be discovered on Earth from biodiversity point of view. Reasons for lack of information vary from unsafe travelling to uninterest resulting from low cost-benefit ratio in scientific terms. Those factors, however, are also in constant change and blank areas continue to disappear from the world map.

West Africa, and civil war-torn Liberia within, is one of those regions, where there is still a lot to discover. The country hosts unique flora and fauna with endemic species due its geology and climate, as well as it has preserved relatively large areas of intact primary rain forests. The rich biodiversity of Liberia is an invaluable asset and a natural heritage that needs to be preserved for future generations. The fact that until 2010 three new butterfly species were discovered and four more have been described since then, only in Nimba region (Sáfián pers. comm.), shows the richness and justifies further research.

Some factors, however, limit the possibilities for research and conservation. The second (and last) Liberian civil war ended in 2003, but social and economic recovery of this West African country has been rather slow. The infrastructure was destroyed almost entirely by the wars, which had and still has an impact on society and the economy that affects national financial resources for research and conservation. As for the most popular and well researched taxon, the birds, for example, Liberia is one of the least researched countries in West Africa along with Bissau-Guinea, Mali and Togo (Freeman & Peterson 2019). Therefore, any form of international support for documenting and conserving the unique flora and fauna of Liberia is essential.

Establishing Eastern Nimba Nature Reserve (ENNR) was a step in that direction. Nimba Mountain *(Figure 1)* with its high-quality iron ore stretches from north to south: the southern part is in Liberia and the northern part is shared between Guinea and Ivory Coast. Vegetation cover on Nimba is Guinean Moist Forest and it includes lowland rainforest and savanna woodland. The vegetation merges into lowland forest on the eastern side of the mountains. At higher elevations (about 850 m asl), dense cloud cover is not uncommon resulting in a higher annual rainfall. Cloud (gallery) forests of that moister areas at about 1,000 m host pure stands of the tree-fern *Cyathea cylindrica*. *Garcinia polyantha* dominates the montane forest at even higher elevations (about 1,200 m). The dominant species of the gallery forest are *Parinari excelsa*, primary forest by *Triplochiton scleroxylon*, *Chlorophora regia, Morus mesozygia* etc. At lower elevation, drier mid-altitude forests consist of *Triplochiton scleroxylon, Piptadeniastrum africanum* and *Parkia bicolor* (Forestry Development Authority 2014). Nimba Mountains host several vertebrate endemics to the West African region like e.g. the Nimba Flycatcher *(Melaenornis annamarulae)*, the Rufous Fishing Owl *(Scotopelia ussheri)* or the Nimba Otter Shrew *(Micropotamogale lamottei)*. The northern part of Nimba range has been subject to the strictest nature conservation regulations in Guinea and Ivory Coast for decades.

The Liberian Nimba Mountains have a history of iron ore mining dated back to the 1960s, when the Liberian-American-Swedish Mineral Company (LAMCO) started to exploit that natural resource. Civil wars interrupted mining, but the Liberian government

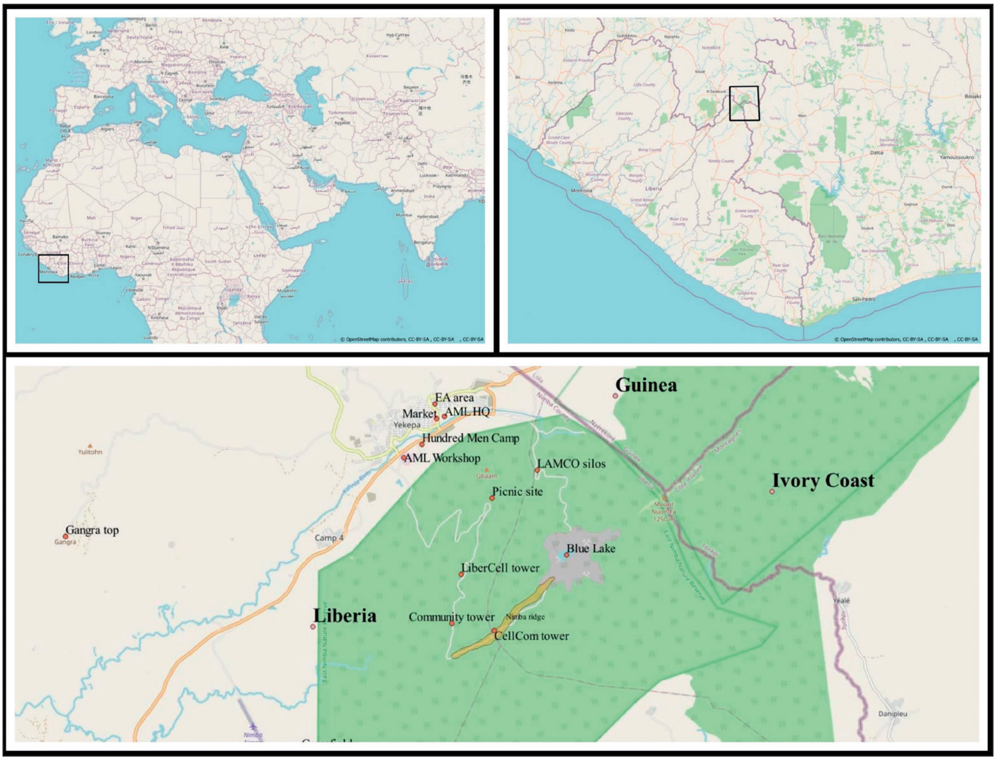


Figure 1. Location of the project area
1. ábra A projektterület földrajzi elhelyezkedése

sold the concession again after war to ArcelorMittal Liberia Limited (AM). According to the deal AM contributes to nature conservation through supporting basic research and the establishment of ENNR.

One of the AM supported research projects was focusing on the African Giant Swallowtail *(Papilio antimachus)*, the largest butterfly in Africa. The author of recent paper visited Nimba region in the frame of that project. Besides the butterfly work, he had the chance to collect information on the local avifauna with special regard to birds of prey species. This article aims to summarize the results of those observations made on three tours to Nimba Mountains between 2015 and2017, and it compares results against recent and historic data. The article contributes to filling the gap on the distribution and biology of birds of prey species in West Africa.

Materials and Methods

The observations were made on a total of 38 birding days in winter periods of 2015–2016, 2016–2017 and 2017–2018. That period refers to the dry season in Liberia when it rains only occasionally. A characteristic weather event of the dry season is the arrival of *harmattan* wind from northeast. That hot and dry wind usually lasts for a few days and changes the landscape by sucking out the moisture from the vegetation. Observations were limited spatially to open areas of Nimba Mountains – mostly hilltops frequented by butterflies – and temporally to diurnal periods. Those limitations negatively affected the detectability of birds of prey species dwelling in dense forest habitats (Accipitridae) and nocturnal species (owls). In addition, timing allowed observing also wintering and migrating species.

The equipment consisted of 10×42 EL Swarovski binoculars and a Swarovski ATS 80 20×60 spotting scope. A Nikon COOLPIX P900 camera was used for photographing. Species identification was based on the guidebook Birds of Western Africa (Borrow & Demey 2014).

The main source of historic data was the book *The birds of Mount Nimba, Liberia* (Colston & Curry-Lindahl 1986). The book summarizes the bird observations from the period 1963–1982, when LAMCO ran a biological research station and collected data on the habitats and wildlife of the area. Another important source of information was the *Zoological assessment* part of the environmental and social impact assessment report for AM (Phalan 2010). Two digital databases are also referred to. One is the former African Raptor Databank (ARDB), which has been transformed and extended forming the Global Raptor Impact Network (GRIN, www.globalraptors.org). ARDB site collected historic and recent data specifically on the presence of birds of prey species across Africa. The other online application is eBird (www.ebird.org), which collects observations globally on every bird species. Data was retrieved from both online applications in October 2020.

Results and Discussion

During the four tours observations occurred on 38 days in total and 20 species were recorded on 106 occasions. Observed birds of prey species are listed in *Table 1*, while *Table 2* summarizes birds of prey species present historically or recently in the region, but not recorded during this project. A full description of the records can be found in *Table 3.*

Although monitoring raptor species was not the primary aim of the project and subsequently time effort was not maximized on raptor observation, the results give a comprehensive picture of the birds of prey fauna of the Liberian part of Nimba range. Beside the 20 observed species, other 16 birds of prey species *(Table 2)* have been recorded historically (Colston & Curry-Lindahl 1986) or recently (Phalan 2010, eBird), in the area but were not observed during the recent project. Those species, however, have a single or a few records only, thus they can be considered as rare vagrants.

The "history" of the observed species can be summarized as follows.

Black-winged Kite *(Elanus caeruleus)* Black-winged Kite is one of the two species that has not been reported historically from the area despite the long-term biodiversity monitoring between the 1960s and 1980s. In the ARDB database, there is only one record of the species near Monrovia (ARDB). *Andrews*, however, reports the species five times between October 2012 and March 2013; likely the same wintering individual (eBird). During the study period

Table 1. The birds of prey species observed between 2015 and 2017 in the frame of the project, indicating the occurrence of historic or other recent records

1. táblázat A projekt keretében 2015–2017 között megfigyelt ragadozómadár-fajok listája, megjelölve az egyéb korábbi vagy recens megfigyeléseket

Nr.	**Species name**		**IUCN status**	**Suggested status in Nimba Mountains**	**Year of observation**	**Nimba book**	**ARDB**	**eBird**
	English name	*Latin name*						
1	Black-winged Kite	*Elanus caeruleus*	Least concern	unknown – possible vagrant	2017	-	+	+
2	Bat Hawk	*Macheiramphus alcinus*	Least concern	unknown – potential, but unlikely breeder	2016	+	+	+
3	European Honey Buzzard	*Pernis apivorus*	Least concern	regular winter visitor	2015, 2016, 2017	+	+	+
4	Palm-nut Vulture	*Gypohierax angolensis*	Least concern	regular – probably only regular visitor as required habitat for nesting is missing in the Liberian side of Nimba range	2015, 2016, 2017	+	+	+
5	Red-necked Buzzard	*Buteo auguralis*	Least concern	resident – breeder	2015, 2016, 2017	+	+	+
6	Lizard Buzzard	*Kaupifalco monogrammicus*	Least concern	resident – breeder	2015, 2016, 2017	+	+	+
7	Crowned Eagle	*Stephanoaetus coronatus*	Near threatened	unknown – potentially breeding in the area	2017	+	+	+
8	Ayres's Hawk Eagle	*Hieraaetus ayresii*	Least concern	resident – likely breeder	2015, 2017	+	+	+
9	Booted Eagle	*Hieraaetus pennatus*	Least concern	rare winter visitor	2015, 2016	+	-	-
10	Cassin's Hawk Eagle	*Aquila africana*	Least concern	resident – likely breeder	2015, 2016	+	+	+
11	Western Marsh Harrier	*Circus aeruginosus*	Least concern	regular winter visitor	2015, 2016, 2017	+	+	+
12	African Harrier Hawk	*Polyboroides typus*	Least concern	resident – breeder	2015, 2016, 2017	+	+	+
13	Black Kite / Yellow-billed Kite	*Milvus migrans / M. aegyptius*	Least concern	winter visitor – regular visitor	2015, 2016, 2017	+	+	+
14	Shikra	*Accipiter badius*	Least concern	unknown	2016	+	+	-
15	Black Sparrowhawk	*Accipiter melanoleucus*	Least concern	unknown	2015	+	+	+
16	Common Kestrel	*Falco tinnunculus tinnunculus / F. t. rufescens*	Least concern	regular winter visitor – likely vagrant	2015, 2016, 2017	+	-	-
17	Gray Kestrel	*Falco ardosiaceus*	Least concern	unknown – likely breeder	2015, 2016, 2017	-	+	+
18	Eurasian Hobby	*Falco subbuteo*	Least concern	rare winter visitor	2017	+	-	-
19	Lanner Falcon	*Falco biarmicus abyssinicus*	Least concern	resident – breeder	2015, 2016, 2017	+	-*	-
20	(African) Peregrine Falcon	*Falco peregrinus minor*	Least concern	resident – potential, but unlikely breeder	2015, 2016	+	-*	+

*indicates that Nimba region is on the edge of breeding distribution

Table 2. Birds of prey species with historic or recent records, but not observed during the project visits between 2015 and 2017

2. táblázat A területen korábban vagy recensen megfigyelt ragadozómadarak listája, amelyek nem kerültek szem elé a projekt során

Nr	Common name	Latin name	IUCN status	Reference	
				Colston & Curry-Lindahl (historic)	ebird (recent)
1	Scissor-tailed (formerly: swallow-tailed) Kite	*Chelictinia riocourii*	Least concern	+	-
2	African Cuckoo-hawk	*Aviceda cuculoides*	Least concern	+	+
3	Common Buzzard	*Buteo buteo*	Least concern	+	-
4	Grasshopper Buzzard	*Butastur rufipennis*	Least concern	-	+
5	Long-crested (hawk) Eagle	*Lophaetus occipitalis*	Least concern	+	-
6	Wahlberg's Eagle	*Aquila wahlbergi*	Least concern	-	+
7	Red-chested Goshawk	*Accipiter tousselini*	Least concern	-	+
8	African Goshawk	*Accipiter tachiro*	Least concern	+	-
9	Red-legged (formerly: Western Little) Sparrowhawk	*Accipiter erythropus*	Least concern	+	-
10	Long-tailed Hawk	*Urotriorchis macrourus*	Least concern	+	-
11	Bateleur	*Terathopius ecaudatus*	Near threatened	+	-
12	Short-toed Snake Eagle	*Circaetus gallicus*	Least concern	+	-
13	Brown Snake Eagle	*Circaetus cinereus*	Least concern	-	+
14	Congo Serpent Eagle	*Dryotriorchis spectabilis*	Least concern	+	-
15	Lesser Kestrel	*Falco naumanni*	Least concern	+	-
16	African Hobby	*Falco cuvierii*	Least concern	+	+

covered in this article, the species was observed only once, on the outskirts of Yekepa. Black-winged Kite is probably a rare, but regular visitor, which may occur in the region more frequently in the future, if the habitat becomes more open and drier because of climate change.

Bat Hawk *(Macheiramphus alcinus)* Several records exist from the foothills of Nimba (Colston & Curry-Lindahl 1986). According to ARDB the species is resident but sparsely occurring in Nimba region (ARDB). There is only one record of the species for Yekepa in 2014 (eBird). The single record of the species in this study is in line with literature and confirms the scarce occurrence of Bat Hawk in the area; even that single individual was traveling high above the site. Probably, it has never been common in the area considering its prey base.

European Honey Buzzard *(Pernis apivorus)* The species was reported both in 2009 and 2010 surveys (Phalan 2010). During the operation of the biological station, European Honey Buzzard was one of the seven most frequently observed birds of prey. It wintered regularly in Nimba using various forest habitats, roadside and more open areas in the mined areas, and individuals were observed feeding on fruits (figs) beside invertebrates (Colston & Curry-Lindahl 1986). Recent distribution model indicates sparse occurrence of the species in the Nimba region in non-breeding season (ARDB). That is confirmed by the observations in eBird: the species was observed on seven occasions between 2013 and2017, in the period October – April (eBird). In the past decade, Finnish (https://www.luomus.fi/en/satellite-honey-buzzards), Swedish (Hake *et al.* 2003, Strandberg *et al.* 2012), German (Meyburg *et al.* 2010), Dutch (https://vimeo.com/85808414) and Hungarian (Agostini *et al.* 2019) satellite-tracked individuals proved that Western Africa – including Nimba Mountains and Liberia – is an important wintering area for the species. Both satellite-tracking data and field observations suggest that the species can exploit various forest habitats from primary rain forests to plantations. Some individuals have well-defined wintering areas. Others – mostly immatures – may keep roaming probably due to intra-specific competition (Strandberg *et al.* 2008). During the reported study period, each year a single individual was observed several times. It was always the same individual within years (identified by the patterns of moulted primaries) suggesting that the individual was a wintering bird. Beside that observation, on 13 December 2015 one adult was flushed from the roadside by the car in the Firestone plantation (South Liberia, outside Nimba Mountains).

Palm-nut Vulture *(Gypohierax angolensis)* The species was recorded both during the surveys in 2009 and 2010 (Demey & Molubah 2009, Phalan 2010, Phalan & Lewis 2010). Palm-nut Vulture was described as the most common bird of prey species in the area (Colston & Curry-Lindahl 1986). Model shows the species as a relatively common species in West Africa (ARDB). According to eBird database, the species is not uncommon in Nimba region (eBird). This recent study confirms those findings. Palm-nut Vulture was a common species in Nimba Mountains, but mostly immature individuals were seen in the area. Outside of the project area, one adult male was seen above AMG concession area (port) in Buchanan. In addition, one pair was observed above the Firestone plantation.

Red-necked Buzzard *(Buteo auguralis)* The species is recorded in 2009 and 2010 surveys (Phalan 2010). Researchers of the biological research station reported it as the third most common raptor at Nimba found mostly in forested habitats. In two occasions, the species was found nesting at Nimba in (sub)montane rainforest at about 900 m (Colston & Curry-Lindahl 1986). Recent models also suggest that the species is common in the region (ARDB). According to other recent observations, the species is not uncommon in Nimba region (eBird). Recent study found Red-necked Buzzard a common species in the project area. Observations suggest that there is at least one active eyrie on the western slopes of Mount Nimba (under LiberCell) towards Yekepa. It is likely that a few more pairs nest in the project area.

Lizard Buzzard *(Kaupifalco monogrammicus)* Surveys recorded the species both in 2009 and in 2010 (Phalan 2010); earlier evaluation also described the species as common (Colston & Curry-Lindahl 1986). Species distribution model also refers to the species as not infrequent in Nimba area (ARDB) that is supported also by concrete observations (eBird). Accordingly, recent records confirmed that Lizard Buzzard is still common in the project area. It was regularly observed in open areas around Yekepa, at roadsides and in the rainforest mostly perching above the road. Based on the observations, it is likely that at least two resident pairs can be found within the project area: one in Yekepa and the surrounding fields nearby and another one in the area between the Picnic site and LiberCell tower.

Crowned Eagle *(Stephanoaetus coronatus)* Previous records mention the species only from three or four subsequent years, dating the last observation to 1971. Authors suggested that the species was likely rare because of the hunting-driven decrease of duikers (small antelope) and monkeys, which made up most of the diet of Crowned Eagle (Colston & Curry-Lindahl 1986). In more recent times the species was reported "present" (Phalan 2010). The model predicts rare occurrence of the species in the region (ARDB). There are two records of the species in the region: one from the Liberian (1988) and one from the Guinean side (2004) of Nimba Mountains (eBird). The species was observed only once (2017) during the study period, but then two adult birds were seen over primary rainforest, which is the species' typical habitat. Given that the main prey species populations are strongly depleted due to overhunting, it is rather questionable if the area can support a breeding pair.

Ayres's Hawk Eagle *(Hieraaetus ayresii)* Earlier evaluation referred to the species as rare, but regularly seen in the same savanna area close to the Guinea border (Colston & Curry-Lindahl 1986). More recently, the species was observed only during the 2009 survey (Phalan 2010). Distribution model shows the species as infrequent but regular in the region (ARDB). Independently from the recent project, the species were observed four times between 2012 and2017, always in winter (eBird). The few but regular observations during the recent project and the behaviour of the individual(s) may suggest that there is at least one occupying bird in the project area.

Booted Eagle *(Hieraaetus pennatus)* There was only one record from Yekepa golf course on 2 March 1981, close to the lowland rain forest (Colston & Curry-Lindahl 1986). No other records were found about the species from the region. Distribution model does not predict the species to southwest West Africa including the entire area of Liberia, a big part of Ivory Coast and Ghana and considerable areas in Guinea and Sierra Leone (ARDB). There is no data about the species in the region in the eBird database. The main wintering area of the European population is in the Sahel, one satellite-tracked Spanish Booted Eagle had its main wintering area in the tropical rainforest between Guinea and Sierra Leone (Mellone *et al.* 2013). Climate, geography, and vegetation is similar to that of wintering area in Nimba Mountains, what makes the sightings in 2015 and 2016 less unique. Individuals, however, were seen only one occasion in both years suggesting that they were on the move and did not establish wintering territory. It is noteworthy that in 2015 the bird was seen during the *harmattan* period, so it might have been blown off-course by the strong northeastern wind.

Cassin's Hawk Eagle *(Aquila africana)* Former species evaluation described Cassin's Hawk Eagle as a rare species; there was only one record between 1963 and 1982 (Colston &

Curry-Lindahl 1986). The species was recorded during both 2009 and 2010 surveys (Phalan 2010). The distribution model shows that Cassin's Hawk Eagle is not infrequent in the region of Nimba Mountains (ARDB). The species was observed in 1988 and in 2017 in Nimba Mountains. The latter is a single observation in September, while in 1988 the species was observed three consecutive days (28–30 September) on the Nimba ridge (eBird). According to the observations of the recent study, there was one bird likely occupying an eyrie in 2015, but it remained unclear, if it was only a single individual or there was a pair in the region. The only observation in 2016 and the lack of own observation in 2017 suggests that the species is uncommon in the area.

Western Marsh Harrier *(Circus aeruginosus)* Only two earlier records mention the species – 11 and 19 February 1971 – in the Grassfield, near Yekepa, which likely belong to the same individual (Colston & Curry-Lindahl 1986). The species was not observed in 2009 and 2010 surveys (Phalan 2010). Distribution model predicts sparse occurrence of the species in the area (ARDB). A local birdwatcher recorded the species on four occasions between 2013 and 2016; both sexes were seen (eBird). During the recent study, Western Marsh Harrier was observed each year, once there were even two birds. Repeated observations of the same individual (based on molt) in 2017 suggest that Nimba Mountains serves as wintering site for the species. All individuals were observed over larger grassland areas near Yekepa and up along the mountain ridge.

African Harrier Hawk *(Polyboroides typus)* The species was recorded during two subsequent surveys in 2009 and 2010, which also obtained evidence of breeding (on page 16): *"fully fledged juvenile following an adult at Gangra, with plaintive begging calls, on 26 April 2010"* (Phalan 2010). Earlier evaluation refers to the African Harrier Hawk as the most common bird of prey species (Colston & Curry-Lindahl 1986). Being a generalist species, it forages on a wide spectrum of food sources from fruits through insects (including wasp larvae) to vertebrates. The species seasonally shared the forest and partly the niche in Nimba region with the European Honey Buzzard (Colston & Curry-Lindahl 1986). African Harrier Hawks suggested to be common in Nimba region according to distribution model, which is supported by historic and recent records (ARDB, eBird). Observations between 2015 and2017 confirmed that African Harrier Hawk is still one of the most common raptor species in the region together with Palm-nut Vulture. Behavioral and movement patterns of observed individuals suggested that at least one pair occupying eyrie in the western slopes of Mount Nimba or in the adjacent lower areas. It is likely that more pairs breed in the area. Apart from the Nimba region, one individual was seen above AMG concession area and port in Buchanan.

Black Kite *(Milvus migrans migrans)* / **Yellow-billed Kite** *(Milvus migrans aegyptius / parasitus)* The two subspecies are discussed together, because separation the two subspecies in the field was not possible due to the observation distance and sometimes because of the light conditions. During the operation period of the biological research station the species was seen regularly, but infrequently, mostly over open areas (Colston & Curry-Lindahl 1986). Kites were not recorded in 2009–2010 surveys (Phalan 2010). ARDB indicates

Nimba region as an area with frequent occurrence of both subspecies (ARDB). Andrews reports the species fourteen times from the period 2012 and 2017 adding that Black/Yellow-billed Kites. Recent observations somewhat contradict ARDB results of extrapolations. Although kites were recorded all along the way from Buchanan to Yekepa, the number of observations decreased significantly towards the north. In the Nimba region, kite occurrence seemed to be rather scarce, but when occurring they were seen usually in small flocks. On one occasion, a few individuals were observed gliding and soaring low above the edge of a bush fire near the village of Yekepa, confirming that fire attracts the species, probably because of the easy prey (Borrow & Demey 2014, Gosford 2015).

Shikra *(Accipiter badius)* In January 1968, one female was reported with worn plumage and that is the single record of the species. The individual was likely on migration as the species breed in more northern areas (Colston & Curry-Lindahl 1986). In the 2010 zoological evaluation based on the 2009–2010 surveys and literature data, Shikra is mentioned in reference to Erard (Phalan 2010). However, as there is no concrete record mentioned, it is unclear if that data is independent from the earlier record. ARDB contradicts that showing Liberia and the Nimba region within as a breeding ground only for the species (ARDB). Andrews recorded an immature individual in December (eBird). During the observations between 2015 and 2017, the only record was a male in December 2016 above Blue Lake on a dry slope with grass and scrub vegetation, and small trees above a creek. It was tame and could be approached close.

Black Sparrowhawk *(Accipiter melanoleucus)* There is only one record from Nimba in 1971 (Colston & Curry-Lindahl 1986). The distribution model suggests scarce but regular occurrence of the species in the region (ARDB). Recently, there is record of one individual in April 2013 and in September 2016 an adult and an immature along with a third bird that he heard but did not see (eBird). During the 2015–2017 survey, the species was seen only once from the mountain top of Nimba as it was flying in the distance above the lowland rainforest in Ivory Coast territory. Given its cryptic lifestyle, however, Black Sparrowhawk may be more frequent than observations suggest.

Common Kestrel *(Falco tinnunculus)* In Liberia, both the West African resident *F. t. rufescens* and the European migrant *F. t. tinnunculus* occur. A recovery of a Swiss-ringed bird in 1972 proves the latter (Moreau 1972). Earlier reports describe Common Kestrel as not uncommon; it was regularly seen in various open, grassy habitats in the area (Colston & Curry-Lindahl 1986). Recently, there is one observation from the region recorded during the 2009 survey (Phalan 2010). None one the earlier records identify the subspecies. Other recent sightings are related to the Monrovia area (ARDB, eBird). In recent project, the species was observed in each year between 2015 and2017. Based on the plumage and the behavior of the observed individuals, both subspecies mentioned above occur in Nimba Mountains.

Grey Kestrel *(Falco ardosiaceus)* The species has no record from the period 1963–1982. Even in 2010, when the species was recorded, the following note was added to the observation:

"*One seen c. 2 km west of Gangra on 8 April 2010. The only previous records of this species from the Nimba Range are those of Gatter (1998).*" (Phalan 2010). ARDB database has recent sighting in the area and predicts Nimba Mountains appropriate for the species (ARDB). A local birdwatcher, however, recorded the species twenty times between 2012 and2017, always in the period October–December (eBird), which indicates regular presence of the species. During the reported study period in this project, the species was seen each year. They were using the same type of dry scrublands consisting of patches of shrub and short trees, and relatively low grassland vegetation, where they hunted on Orthoptera (grasshoppers, crickets and locusts) and Anisoptera (dragonflies). Increasing number of observations suggest that the species has gradually moved in the area in the past 20–30 years.

Eurasian Hobby *(Falco subbuteo)* The observation of the species in 1971 in Yekepa was the first record of the species in Liberia (Colston & Curry-Lindahl 1986), although it was already known to be regular in winter in Ivory Coast (Brunel & Thiollay 1969). Zoological evaluation of the Liberian part of Nimba Mountains also mentions the species (Phalan 2010), but in reference to Erard and Brosset (2003). However, as Erard and Brosset's work is mostly a summary of several previous works in the entire Nimba mountain range including the Guinean and Ivory Coast part, and as they did not indicate of the exact locations of observations at the species accounts, it is not clear if their data can evidently be applied also to the Liberian part of the mountains. Satellite-tracking of Eurasian Hobbies confirmed that the species main wintering area is in sub-equatorial Africa, however, they may travel across certain parts of West Africa (Strandberg *et al.* 2008, Meyburg *et al.* 2011). There are no observations recorded in the ARDB and eBird databases from the Nimba area. Despite that the area hosted large flocks of Barn Swallows *(Hirundo rustica)*, House Martins *(Delichon urbicum)* and Swifts (*Apus* spp.) – the most important prey species – Eurasian Hobby was recorded only on two occasions, both in 2017. The Hobbies were hunting in both cases, once on swallows and martins high up in the air and on dragonflies low above the ground, on the other occasion.

Lanner Falcon *(Falco biarmicus abyssinicus)* There is only one record from Mount Nimba ridge (13 January 1982). The observed individual might have been a short-distance intra-African migratory bird breeding no further than the Guinean savanna belt or the Sahel and it might have belonged to the North African subspecies *F. b. erlangeri* (Colston & Curry-Lindahl 1986). Lanner Falcon was recorded both in 2009 and 2010 (Phalan 2010). He comments on the species as: "*One seen between Yekepa and Grassfield on 10 April 2010. A rare dry season visitor to the north of Liberia, expanding southwards as a result of the opening up of the forest (Gatter 1998).*" Indication of subspecies was given in the latter case. ARDB shows Nimba Mountains as an area on the edge of the breeding range, but there is no observation indicated (ARDB). There are no recent records of the species from the Nimba region in the eBird database either despite known birdwatching efforts in Yekepa village between 2012 and 2017. It is especially interesting therefore, that the species was seen every year during the reported study period. In the light of the comments above, it is especially interesting that an adult pair was seen above the village of Yekepa and the forest nearby (Picnic site), once even in the company of an immature bird. They were hunting together clearly as established pairs of falcons do. Once the adults were seen perching together in the canopy of a high tree at the edge of the village; one of them was feeding on a mid-sized bird, while the other one was preening only a few meters away. That pair certainly was in its territory. The species was never seen on higher elevations. Based on the behavior and plumage, as well as on the location the observed Lanner Falcons belong to the *F. b. abyssinicus* (African) race.

African Peregrine Falcon *(Falco peregrinus minor)* Several sightings of the species were recorded between November and March, however only after the deforestation and mining on Nimba mountain top. They highlight that there are no records of Peregrines from the 1960s, when the monitoring program had already been running, but there was still a primary forest on the mountain top. They did not identify the subspecies, however, *F. p. calidus* is mentioned in general without any reference to Nimba as a wintering subspecies in Africa. Peregrine was recorded only during the 2009 survey (Phalan 2010); also, without identifying the subspecies. Thus, it is not possible to decide whether those sightings belonged to resident *(F. p. minor)* or wintering (*F. p. peregrinus* or *F. p. calidus*) birds. The problem of distinction between resident and wintering subspecies was already described in 2003 and Peregrine Falcon, Eurasian Kestrel, and Black Kite were brought as examples, emphasizing that only regular observations in the wintering period could solve the problem (Erard & Brosset 2003). Species distribution model predicts that Peregrines do not breed in the area, but they occur on migration or roaming (ARDB). Recently, there are only two records of the species (without any further details) from 1988 in the Liberian Nimba ridge and in the Guinean side of Nimba in 2004 (eBird). During the observations in the recently reported study period, Peregrine Falcon was observed several times in 2015 and 2016. At least on three occasions, the individuals were seen at close range and the African race *(F. p. minor)* was clearly identified. Mining in Nimba Mountains left several cliffs behind and there are also some natural cliffs in the area that can be appropriate for nesting, however, despite the intensive search no Peregrine Falcon nests were found on the cliffs in the project area.

Conclusions

Historic and recent data allow us to compare species composition of old and new data sets. Species can be divided into three groups:

- 20 species out of the total 36 observed in the Liberian part of Nimba Mountains were recorded both historically and recently;
- 10 species have historic records only, without any recent observations;
- 6 species were observed for the first time only recently *(Figure 1, Figure 3)*.

Among the species observed also then and now, we find common breeding species and winter visitors as well. Their typical habitats include forests, shrublands and grasslands, they do not form a habitat-specific group.

Birds of prey species, observed only between 1963 and1982, include both forest species and species of open habitats. However, most of them have only very few records, thus they can be considered vagrant birds. Considering the research effort (several months per year) and the long run of the biological research station offered more chance to detect rare visitors, compared to the more ad hoc observations recently.

The most interesting group is formed by those species observed recently, but not detected previously. Looking at the pattern, Lanner Falcon must also be added to the list, as it has only a single historic record, but now settled in the area. It would be logical to assume that during the period 1963–1982, when targeted observations for birds were being done, all or most species were recorded and only a few, if any rare forest-dwelling species could have avoided detection. However, out of the six plus one species – Black-winged Kite, Grasshopper Buzzard, Wahlberg's Eagle, Red-chested Goshawk, Brown Snake Eagle, Lanner Falcon and Gray Kestrel – that have not been recorded previously, only the Red-chested Goshawk is a forest-dwelling species. The other ones are more related to wooded or open grassland habitats. Inhabiting open habitats implies a higher likelihood of detection. Lack of records of those species in the previous 19-year period suggests their likely absence previously.

Two species are especially interesting. Gray Kestrels were observed on a number of occasions recently. They use open habitats, often near roads and they are tame – one can get close to them. It is hard to believe that such a conspicuous species went unnoticed for almost two decades. Although Lanner Falcon was mentioned by Colston and Curry-Lindahl (1986), but only once and they suggested that it was a migrant from the Sahel. Even recently, only Phalan (2010) mentions the species: *"One seen between Yekepa and Grassfield on 10 April 2010."* Observations in the project between 2015 and2017 suggest, however, that the species is not only present in the area, but it likely breeds. A pair regularly and a juvenile once were observed just above and around the village of Yekepa. It is hard to believe again that such an obvious bird would have gone unnoticed by expert ornithologists for almost 20 years.

The explanation of the phenomenon may lie in the guidebook to the Liberian bird species in a comment on Lanner Falcon: "*A rare dry season visitor to the north of Liberia, expanding southwards as a result of the opening up of the forest"* (Gatter 1998). Increasing presence of open habitat dwelling species can be an indication of the encroachment of savanna replacing rainforest habitats, which would be in line with climate scenarios (Niang *et al.* 2014). Other study described the long-term decrease of tree species richness and density in Senegal (Gonzalez 2001), which was likely not restricted to the study region of that research. More research is needed, however, to understand the correlation between the presence of those species and local habitat change.

Acknowledgement

The author is grateful to the individuals and organizations who in some form contributed to the implementation of the project. Namely, Dr. Szabolcs Sáfián, head of butterfly conservation research and Ms. Wing-Yunn Crawley, biodiversity manager of AM did their best to support the birds of prey research in Nimba. In addition, AM Liberia and Madárvilág Nonprofit Kft. contributed to the implementation of this project.

*Appendix 1.*Species account of detailed observations in the period 2015–2017
1. melléklet A 2015–2017 közötti időszakban feljegyzett ragadozómadár-fajok megfigyeléseinek részletes leírása

Date	Site name	Coordinates	Nr	Sex	Age	Comment
Black-winged Kite *(Elanus caeruleus)*						
17.12.2017	AML Workshop	7.566572° -8.542879°	1	unknown	adult	9:30 – Perching on a nearby tree using as a vantage point to hunt
Bat Hawk *(Macheiramphus alcinus)*						
16.12.2016	Hundred men camp / AML Workshop	7.566572° -8.542879°	1	unknown	immature	10:30 – Soaring from N to S-SW high above the camp. Probably immature based on the more extended white underpart (compared to adults).
European Honey Buzzard *(Pernis apivorus)*						
01.12.2015	LiberCell	7.535047° -8.527079°	1	male	adult	12:00 – Flying over heading north. It was moulting the 4. primaries
02.12.2015	LiberCell	7.535047° -8.527079°	1	male	adult	11:12 – The same individual as yesterday. Flying over.
07.12.2015	LiberCell	7.535047° -8.527079°	1	male	adult	11:36 – One individual was flying over – the same individual as earlier.
10.12.2015	LiberCell	7.535047° -8.527079°	1	male	adult	11:20 – The same, previously seen moulting individual was gliding from northeast to southwest
13.12.2015	Firestone plantation	6.307396° -10.435700°	1	unknown	unknown	NOT in Nimba area. On 13 December 2015 one adult was seen also in the Firestone plantation. It was flushed by the car from the roadside. Dutch sat tracked bird crossed the area in 2013.
06.12.2016	Yekepa	7.577121° -8.533847°	1	unknown	unknown	14:30 – Soaring high above AML Headquarter. Moulting primaries.
07.12.2016	LiberCell	7.535047° -8.527079°	1	unknown	adult	12:10 – Soaring above the site. Moulting heavily.
17.12.2016	Blue Lake	7.540280° -8.497993°	1	unknown	unknown	12:00 – Flying high above the mountain top above Blue Lake, towards NE
16.12.2017	CellCom	7.519895° -8.517937°	1	unknown	unknown	15:30–17:30 – 1 individual was flying low above the top of Nimba
18.12.2017	Picnic site	7.555649° -8.518559°	1	unknown	unknown	11:00–11:20 – 1 individual was mobbed by a pair of Lanner Falcon

Date	Site name	Coordinates	Nr	Sex	Age	Comment
Palm Nut Vulture *(Gypohierax angolensis)*						
25.11.2015	Buchanan	5.861408° -10.031430°	1	male	adult	NOT in Nimba area. One adult male was seen above Arcelor Mittal concession area and port in Buchanan.
25.11.2015	Firestone plantation	6.484882° -10.322318°	2	pair	adult	NOT in Nimba area. One pair was observed also above the Firestone plantation
29.11.2015	LiberCell	7.535047° -8.527079°	2	unknown	immature	An immature circled up above the security office 29/11/2015 LiberCell tower; Morning – Immature individual flying over; Afternoon – 2 immature individuals flying over
30.11.2015	LiberCell	7.535047° -8.527079°	1	unknown	immature	Morning – One immature individual passed through towards northeast then soaring up above LiberCell tower
02.12.2015	LiberCell	7.535047° -8.527079°	2	unknown	immature	12:55 – Two individuals (an immature and an adult male) soaring up above LiberCell; 13:08 – An immature individual is playing in the air
07.12.2015	LiberCell	7.535047° -8.527079°	1	unknown	immature	12:42 – An immature, moulting individual was flying by towards south
08.12.2015	LiberCell	7.535047° -8.527079°	1	unknown	immature	10:12 – An immature individual arrived from the south and the returned after two circles above the tower
11.12.2015	LAMCO silos/ Blue Lake	7.541275° -8.498285°	1	unknown	immature	16:41 – An immature was flying towards Blue Lake; 17:03 – An immature (maybe the previously seen) was soaring up above the (Guinea side) peak at Blue Lake
12.12.2015	Nimba ridge	From 7.512826° -8.529177° to 7.533939° -8.502132°	1	unknown	immature	15:18 – An immature individual was perching on a tree on top the ridgeline on Yekepa side between CellCom and Community tower.
07.12.2016	LiberCell	7.535047° -8.527079°	2	male / unknown	adult / immature	11:40 – Adult male attacked a Booted Eagle between CellCom and LiberCell; 11:50 – An immature arrived low and soared before heading towards Guinea
11.12.2016	Hundred men camp / AML Workshop	7.566572° -8.542879°	2	unknown	unknown / immature	09:59 – An immature and an adult circled up with an adult that headed towards northwest
14.12.2016	Yekepa	7.577121° -8.533847°	1	unknown	immature	7:40 – Soaring up above the village (security building)
15.12.2016	Picnic site	7.555649° -8.518559°	1	unknown	immature	10:00 – An immature soared above the site

Date	Site name	Coordinates	Nr	Sex	Age	Comment
17.12.2016	Blue Lake	7.540280° -8.497993°	1	unknown	adult	13:00 – An adult flew southwards high
19.02.2017	Gangra top	7.547211° -8.633461°	2	unknown	juvenile / subadult	17:00 – A juvenile was soaring low and a subadult was displaying above the top
14.12.2017	CellCom	7.519895° -8.517937°	1	unknown	immature	14:00–15:00 – An immature was perching on a small tree on the ridge
17.12.2017	CellCom	7.519895° -8.517937°	1(2)	unknown	immature	10:00 – An immature close to the ridge; 14:45–15:30 – An immature was observed
Red-necked Buzzard *(Buteo auguralis)*						
28.11.2015	LiberCell	7.535047° -8.527079°	1	unknown	unknown	11:15 Soaring up from the valley (Camp Four) towards CellCom tower
02.12.2015	LiberCell	7.535047° -8.527079°	1	unknown	unknown	Around 16:00 – One individual
10.12.2015	LiberCell	7.535047° -8.527079°	2	unknown	unknown	11:25 – Two individuals were flying over, one soaring high and the other one was soaring up from below from the direction of Camp Four. Both headed to the Nimba ridge (CellCom tower); 11:51 – One of the individuals returned and stooped with folded wings from high above LiberCell tower towards Yekepa/ Camp Four
11.12.2015	LiberCell	7.535047° -8.527079°	1(2)	unknown	adult	11:10 – One individual with freshly growing primaries was soaring up from under the ridgeline from the direction of Camp Four heading towards Blue Lake; 12:38 – An individual was‚rollercoasting’ to under the LiberCell ridgeline towards Camp Four, then soaring up again
12.12.2015	Nimba ridge	From 7.512826° -8.529177° to 7.533939° -8.502132°	1	unknown	unknown	14:48 – One individual was soaring up between CellCom tower and Blue Lake then stooping toward Yekepa side of the ridge (probably attacking an Ayres's Hawk Eagle)
10.12.2016	Nimba ridge	From 7.512826° -8.529177° to 7.533939° -8.502132°	1	unknown	unknown	13:00 – Gliding along the ridge
11.12.2017	LiberCell	7.535047° -8.527079°	1	unknown	unknown	12:05 – Soaring up from below to high above the tower. Light harmattan, 20–25°C

Date	Site name	Coordinates	Nr	Sex	Age	Comment
12.12.2017	Blue Lake	7.540280° -8.497993°	2	unknown	unknown	10:00 – 2 individuals soared near the top (close to the border). Area between Blue Lake and Guinea border
13.12.2017	Yekepa	7.577121° -8.533847°	1	unknown	unknown	1 individual soaring high above the village
Lizard Buzzard *(Kaupifalco monogrammicus)*						
30.11.2015	LiberCell	7.535047° -8.527079°	1	unknown	adult	Morning – Soaring up into a cloud and disappearing to north
02.12.2015	LiberCell	7.535047° -8.527079°	1	unknown	unknown	12:42 – Soaring up high above the hill
05.12.2015	Yekepa	7.577121° -8.533847°	1	unknown	unknown	08:39–09:13 One individual was perching on a standing dead tree above Yekepa Youth Centre apparently hunting
08.12.2015	Hundred men camp/AML workshop	7.566572° -8.542879°	2	unknown	unknown	16:52 – Two individuals were perching on the wire of the distribution (electric) line. One of them caught a lizard
11.12.2015	LiberCell	7.535047° -8.527079°	1	unknown	unknown	11:40 – Shortly soaring then landing on a high tree between LiberCell and Picnic site. It flew off a few minutes later and joined to a soaring Peregrine above the same spot
12.12.2015	Hundred men camp/AML workshop	7.566572° -8.542879°	1	unknown	unknown	10:05 – One individual was perching on the wire at same spot as a few days earlier
12.12.2015	LiberCell	7.535047° -8.527079°	1	unknown	unknown	16:09 – One individual was landing on a tree on the side of the CellCom road just down of LiberCell tower (between LiberCell tower and Picnic site). Flushed by the car landed on an other tree near the road. Very ‚tame', it let the car very close
06.12.2016	Yekepa	7.577121° -8.533847°	1	unknown	unknown	Morning – soaring above the village
07.12.2016	Picnic site	7.555649° -8.518559°	1	unknown	unknown	12:30 – Above the site
08.12.2016.	Hundred men camp/AML workshop	7.566572° -8.542879°	1	unknown	unknown	10:30 – Soaring and hunting along the road
12.12.2016	Picnic site	7.555649° -8.518559°	1	unknown	unknown	12:30 – Perching on a tree (6-7 m) at the edge of a forest clearing. Very tame

Date	Site name	Coordinates	Nr	Sex	Age	Comment
16.12.2016	Yekepa	7.577121° -8.533847°	1	unknown	unknown	13:30 – In the village, near the canteen
10.12.2017	Picnic site	7.555649° -8.518559°	1	unknown	unknown	9:00–9:30 – It was perching on a high branch in the otherwise closed forest above the road up to LiberCell tower between Picnic site and workshop. Harmattan wind arrived early morning, with strong NE wind, 20–25°C
12.12.2017	Blue Lake	7.540280° -8.497993°	1	unknown	unknown	10:00 – 1 individual soaring. Area between Blue Lake and Guinea border
16.12.2017	Picnic site	7.555649° -8.518559°	1	unknown	unknown	12:58 – gliding high towards Yekepa
17.12.2017	Hundred men camp/AML workshop	7.566572° -8.542879°	1	unknown	unknown	9:30 – perching on poles on the side of the road and hunting on prey in the roadside ditch
Crowned Eagle *(Stephanoaetus coronatus)*						
12.12.2017	Blue Lake	7.540280° -8.497993°	2	unknown	adult	10:00 – Two adults were soaring above the valley between Blue Lake and LiberCell tower often submerging to the old forest in the valley and coming up again
Ayres's Hawk Eagle *(Hieraaetus ayresii)*						
02.12.2015	LiberCell	7.535047° -8.527079°	1	unknown	adult	16:00 – One adult individual is flying over
10.12.2015	LiberCell	7.535047° -8.527079°	1	unknown	adult	13:23–13:38 – It came along LiberCell ridge from up heading towards Yekepa down to the Picnic site. There it started to soar and went up very high. It stooped twice, but not on prey, then it stopped mid-air against the wind for a while (like Short-toed Eagles, but never hovered). It headed back along the ridge, then turned towards the towers on the top. It had a distinctive white head like in the previous case; 14:50 – It stooped towards the Nimba ridge; 15:00 – It came very low and close to LiberCell tower. Apparently, the observers did not disturb the bird. It flew back to the towers on Nimba ridge
12.12.2015	Nimba ridge	From 7.512826° -8.529177° to 7.533939° -8.502132°	2	unknown	adult	14:48 – One individual (light morph) was gliding above the ridgeline from the direction of CellCom tower towards Blue Lake; 14:58 – A dark morph individual was gliding above the ridge from the eastern side of Nimba towards Blue Lake (to the same direction as the other individual)

Date	Site name	Coordinates	Nr	Sex	Age	Comment
16.12.2017	CellCom	7.519895° -8.517937°	1	unknown	unknown	15:30–17:30 – Hunting along the ridge – two attacks into the canopy without result
18.12.2017	Picnic site	7.555649° -8.518559°	2	unknown	unknown	12:00–13:00 – 2 individuals soaring above the site were observed
Booted Eagle *(Hieraaetus pennatus)*						
10.12.2015	LiberCell	7.535047° -8.527079°	1	unknown	unknown	11:55 – An individual (medium phase) arrived low above LiberCell, it soared up and headed towards Nimba ridge / CellCom tower.
07.12.2016	LiberCell	7.535047° -8.527079°	1	unknown	unknown	11:40 – A Palm Nut Vulture attacked it
Cassin's Hawk Eagle *(Aquila africana)*						
29.11.2015	LiberCell	7.535047° -8.527079°	1	unknown	unknown	Morning – Soaring high from west to east
30.11.2015	LiberCell	7.535047° -8.527079°	1	male	adult	Late morning – It appeared between LiberCell tower and Picnic site, flying low and calling. It perched twice on two still standing dead wood lower on the hill, first on Yekepa side, then on the side of the road up the ridge. It was calling when flying off and changing the perch site. Then it soared up, spent a few minutes above the site and left toward the ridge. Apparently, it did not care much of the observers. Adult male (?)
02.12.2015	LiberCell	7.535047° -8.527079°	1(2)	male	adult	14:05 – A displaying individual was coming from high from the direction of Blue Lake,,rollercoasting' then stooping down under the LiberCell hilltop towards the valley to Camp Four. 14:39 – An individual (likely the previous one) was soaring up from the Picnic site towards the Nimba ridge
15.12.2016	LiberCell	7.535047° -8.527079°	1	unknown	adult	14:00 – Perching on a tree above the asphalt road between LiberCell tower and Picnic site. Very tame, let the car close
Western Marsh Harrier *(Circus aeruginosus)*						
26.11.2015	Nimba ridge	From 7.512826° -8.529177° to 7.533939° -8.502132°	1	unknown	immature	Late afternoon – A immature individual (in 1cy plumage) soaring above the peak above Blue Lake (Guinea side) heading to north

Date	Site name	Coordinates	Nr	Sex	Age	Comment
10.12.2016	Hundred men camp/AML workshop	7.566572° -8.542879°	1	male	adult	9:15 – Flying low and scanning the reed and grassland area between the workshop and the village
11.12.2016	Hundred men camp/AML workshop	7.566572° -8.542879°	2	unknown	unknown	9:00 – Above the site, where one ind was seen on 10.12.2016. Soaring high above towards N. They molted the primaries
11.12.2017	CellCom	7.519895° -8.517937°	1	female	adult	1 adult female was hunting low above the grassland, sometimes soaring up a little higher. Light harmattan, 20–25°C
16.12.2017	CellCom	7.519895° -8.517937°	1	female	adult	15:30–17:30 – 1 adult female was seen hunting low above the grassland (maybe the previously observed individual)
18.12.2017	Picnic site	7.555649° -8.518559°	1	female	adult	10:30 – 1 adult female soaring up was observed
African Harrier Hawk *(Polyboroides typus)*						
25.11.2015	Buchanan	5.861408° -10.031430°	1	unknown	adult	NOT in Nimba area. One individual was seen above ArcelorMittal concession area and port in Buchanan
28.11.2015	LiberCell	7.535047° -8.527079°	2	pair	adult	10:37 – Two individuals (male and female) playing and displaying above/between LiberCell and Picnic site; 11:06 Soaring up on a thermal into the clouds towards CellCom tower
30.11.2015	LiberCell	7.535047° -8.527079°	1	unknown	adult	Morning – One individual flying over
02.12.2015	LiberCell	7.535047° -8.527079°	2	pair	adult	11:24 – Two individuals. One is displaying,‚going rollercoaster', clapping with its wings above its back and calling; 15:00 – One individual is soaring towards the Nimba ridge
07.12.2015	LiberCell	7.535047° -8.527079°	1	male	adult	11:36 – Displaying individual
10.12.2015	LiberCell	7.535047° -8.527079°	1	unknown	adult	10:33 – One individual was flying from the Nimba ridge towards Yekepa; 12:08 – One individual arrived from Yekepa and headed towards Community tower along the LiberCell ridge
10.12.2016	Hundred men camp/AML workshop	7.566572° -8.542879°	1	unknown	unknown	9:00 – It soared up with prey and flew to a wood nearby (nest?)

Date	Site name	Coordinates	Nr	Sex	Age	Comment
11.12.2016	Hundred men camp/AML workshop	7.566572° -8.542879°	2	pair	adult	10:50 – Soaring together above the area
16.12.2016	Gangra top	7.547211° -8.633461°	1	unknown	unknown	17:50 – Hunting by moving around the top of bushed and low branches of trees near the road.
17.12.2016	Yekepa	7.577121° -8.533847°	1	unknown	unknown	9:00 – Looking for something on the low pine trees at the market in the centre of Yekepa. It was not afraid of men and cars
15.12.2017	CellCom	7.519895° -8.517937°	1	unknown	unknown	11:30–12:00 – 1 individual was observed
17.12.2017	CellCom	7.519895° -8.517937°	1	unknown	unknown	14:45–15:30 – 1 immature was observed flying above the LoneStar tower
18.12.2017	Picnic site	7.555649° -8.518559°	2	unknown	adult / immature	12:00–13:00 – an immature and an adult were observed as they soared up
Black Kite / Yellow-billed Kite *(Milvus migrans) / (Milvus migrans aegyptius)*						
06.12.2015	LiberCell	7.535047° -8.527079°	3	unknown	unknown	Three individuals were soaring from northeast to southwest. Intact plumage (immature birds?).
11.12.2015	Hundred men camp / AML workshop	7.566572° -8.542879°	4	unknown	unknown	13:45 – Four individuals were hunting very low above the bush fire along the road catching escaping animals
06.12.2016	Yekepa	7.577121° -8.533847°	1	unknown	unknown	15:00 –Above the village
07.12.2016	Picnic site	7.555649° -8.518559°	3	unknown	unknown	13:20 – Soaring above the site
12.12.2017	Blue Lake	7.540280° -8.497993°	6	unknown	unknown	Area between Blue Lake and Guinea border; 10:00 – 6 individuals flying high to direction of W – NW
16.12.2017	Picnic site	7.555649° -8.518559°	1	unknown	unknown	1 individual gliding high from the top towards Yekepa
Shikra *(Accipiter badius)*						
16.12.2016	Blue Lake	7.540280° -8.497993°	1	male	adult	Afternoon. On one of the terraces above the lake, in dry, open hillside with grass and bushy vegetation and low tree. Tame, but flew towards the eastern side of Nimba after bearing a few minutes of photographing

Date	Site name	Coordinates	Nr	Sex	Age	Comment
Black Sparrowhawk *(Accipiter melanoleucus)*						
29.11.2015	Nimba ridge	From 7.512826° -8.529177° to 7.533939° -8.502132°	1	unknown	unknown	Afternoon – one individual flying on the eastern side of Nimba high above the lowland forest
Common Kestrel *(Falco tinnunculus)*						
26.11.2015	Nimba ridge	From 7.512826° -8.529177° to 7.533939° -8.502132°	1	male	adult	Late afternoon – An adult male individual of relatively large size was perching and hunting from the perch on the ridgeline (same place as later a Grey Kestrel) between the Community and CellCom tower
09.12.2016	CellCom	7.519895° -8.517937°	1	male	adult	16:45 – Soaring up from the direction of Yekepa to the tower, then glided along the ridge toward SE
10.12.2017	LiberCell	7.535047° -8.527079°	1	male	adult	9:00–9:30 – An adult male hovered and hunted successfully on large insects (Orthoptera). Harmattan wind arrived early morning, with strong NE wind, 20–25°C
14.12.2017	CellCom	7.519895° -8.517937°	1	unknown	unknown	14:00–15:00 a heavily moulting individual was seen, but due to light conditions it was impossible to identify age or sex
16.12.2017	CellCom	7.519895° -8.517937°	2	male / female	adult	11:10 – 1 adult female (likely a local *F. t. rufescens*) was seen hovering; 11:20 – 1 adult male (likely a wintering *F. t. tinnunculus*) was seen hunting while on the move from N to S
17.12.2017	CellCom	7.519895° -8.517937°	2	male / female	adult	11:00 – 1 adult male was observed; 14:45–15:30 – 1 adult female was observed
18.12.2017	Picnic site	7.555649° -8.518559°	1	unknown	unknown	10:30–11:00 – 1 individual was observed
Grey Kestrel *(Falco ardosiaceus)*						
29.11.2015	LiberCell	7.535047° -8.527079°	1	unknown	unknown	Afternoon – one individual was flying over
03.12.2015	EA area, Yekepa	7.581038° -8.534307°	1	male	adult	08:21 – An adult male flew displaying (flip-flopping) from the Yekepa CellCom tower towards the market. He landed for a second on the large tree in front of EA area entrance gate other side of the road

Date	Site name	Coordinates	Nr	Sex	Age	Comment
12.12.2015	Nimba ridge	From 7.512826° -8.529177° to 7.533939° -8.502132°	1	male	adult	13:30 – An adult (male?) was hunting between Community tower and CellCom tower from perch successfully and caught a larger, green-brown locust. Very confidential, let the car come close
12.12.2015	AML HQ, Yekepa	7.581038° -8.534307°	1	male	adult	16:30 – One adult individual (male?) was coming from the direction of Yekepa market to the AML Headquarter and landing on a large Christmas-tree near the HQ building (direction of Guinea). Then it left towards the workshop after a few minutes
13.12.2016	Nimba ridge	From 7.512826° -8.529177° to 7.533939° -8.502132°	1	unknown	unknown	16:45 – Gliding from the SW edge of Nimba ridge towards LiberCell
14.12.2016	Hundred men camp / AML workshop	7.566572° -8.542879°	1	unknown	unknown	15:25 – Further south of Hundred men camp/AML workshop, near the concession entrance gate (7.557373° -8.553866°). Perching on trees near the road, apparently hunting
15.12.2016	LiberCell	7.535047° -8.527079°	1	unknown	immature	12:50 – Soaring and hunting around LiberCell tower. Later landed and perched on a dead tree on the slope towards Yekepa just below LiberCell tower.
17.12.2016	Blue Lake	7.540280° -8.497993°	1	unknown	unknown	12:00 – Perched on a tree on the top above Blue Lake (towards the Guinea border)
15.12.2017	Picnic site	7.555649° -8.518559°	2	unknown	unknown	11:40–12:10 – 2 individuals hunting on dragonflies
15.12.2017	CellCom	7.519895° -8.517937°	1	unknown	adult	11:30–12:00 – 1 individual was perching and hunting on insects using small trees on the ridge as vantage points
Eurasian Hobby *(Falco subbuteo)*						
16.12.2017	CellCom	7.519895° -8.517937°	1	unknown	unknown	15:30–17:30 – 1 individual hunting above the ridge, most likely on swifts (*Apus spp.*), House Martins *(Delichon urbicum)* or Barn Swallows *(Hirundo rustica)*
18.12.2017	Picnic site	7.555649° -8.518559°	1	unknown	unknown	12:00–13:00 – 1 individual was observed that was hunting low above the vegetation (probably on dragonflies)
Lanner Falcon *(Falco biarmicus abyssinicus)*						
27.11.2015	Yekepa	7.577121° -8.533847°	2	pair	adult	Early afternoon – A pair of Lanner Falcon was soaring up cca. above Yekepa centre/market and drifted away towards AML workshop place

Date	Site name	Coordinates	Nr	Sex	Age	Comment
01.12.2015	Yekepa	7.577121° -8.533847°	1	unknown	adult	08:00–08:30 – Passing not too high above the area obviously hunting
04.12.2015	Yekepa	7.577121° -8.533847°	2	pair	adult	08:39 – A pair is soaring low above the southwestern part of Yekepa and disappeared to southwest direction obviously hunting
06.12.2016	Yekepa	7.577121° -8.533847°	2	pair	adult	14:40 – Soaring in pairs, the male displaying. At 15:30 – the male returned again.
14.12.2017	EA area, Yekepa	7.581038° -8.534307°	2	pair	adult	08:30 – 2 adult lanners (a pair) just outside of EA area: one is feeding on a prey on a high branch of a tall tree and its mate perching just a few metres away on the same tree
16.12.2017	Picnic site	7.555649° -8.518559°	3	pair / unknown	adult / immature	11:40 – An adult pair and an immature (2cy) individual were observed chatting with each other, soaring and stooping into the valley between the Picnic site and Nimba top (CellCom tower) – one lanner soared up later
18.12.2017	Picnic site	7.555649° -8.518559°	2	pair	adult	11:00–11:20 – The male of a pair lanners was mobbing a European Honey Buzzard; the female came later, and both lanners soared up towards NW to return later at very high altitude seemingly catching dragonflies
(African) Peregrine Falcon *(Falco peregrinus minor)*						
28.11.2015	LiberCell	7.535047° -8.527079°	1	female	adult	11:24 – Gliding down along the slopes (on Camp Four side) from Community tower towards Picnic site then stooping to the other side of the hill between LiberCell and Picnic site partly between the large trees attacking flock of swallows on the other side of the hill. Close to the observers when appeared. Not shy, it could be observed from close range. Not seen again, no proof of successful hunting
10.12.2015	LiberCell	7.535047° -8.527079°	1	female	adult	12:50–12:57 – One individual arrived from the direction of the CellCom tower at mid-altitude, then (maybe because of realizing the presence of observers) started to soar up and left towards CellCom tower
11.12.2015	LiberCell	7.535047° -8.527079°	1	male	adult	11:45 – A soaring adult male above the area between LiberCell and Picnic site. Slowly drifting away while soaring towards Guinea border above the valley between Picnic site and Blue Lake
15.12.2016	Picnic site	7.555649° -8.518559°	1	unknown	unknown	10:10 – Stooping very fast across the airspace above the site and disappeared in the valley

References

Agostini, N., Prommer, M., Váczi, M. & Panuccio, M. 2019. Repeated large-scale loop migrations of an adult European Honey Buzzard. – Avocetta 43: 13–21. DOI: 10.30456/AVO.2019103

Borrow, N. & Demey, R. 2014. Birds of Western Africa. – Princeton Field Guides, 2nd ed. – Princeton University Press, Princeton, U.S.

Brunel, J. & Thiollay, J. 1969. Liste Préliminaire des oiseaux de Côte d'Ivorie [Preliminary list of birds of Ivory Coast]. – Alauda 37: 230–254. (in French)

Colston, P. R. & Curry-Lindahl, K. 1986. The birds of Mount Nimba, Liberia. – British Museum (Natural History), London

Forestry Development Authority 2014. East Nimba Nature Reserve management plan. Liberia. – https://liberia.arcelormittal.com/~/media/Files/A/ArcelorMittal-Liberia/reports-and-presentations/ennr-mgt-plan-2014-final.pdf

Freeman, B. & Peterson, A. T. 2019. Completeness of digital accessible knowledge of the birds of western Africa: Priorities for survey. – The Condor 121(3): 1–10. DOI: 10.1093/condor/duz035

Gonzalez, P. 2001. Desertification and a shift of forest species in the West African Sahel. – Climate Research 17(2): 217–228. DOI: 10.3354/cr017217

Gosford, R. A. 2015. Ornithogenic Fire: Raptors as Propagators of Fire in Australian Savanna. – Raptor Research Foundation, annual conference. 4–8 November 2015. Retrieved on 31 December 2015. – http://www.raptorresearchfoundation.org/wp-content/uploads/2015/11/2015_conference_program.pdf

Hake, M., Kjellén, N. & Alerstam, T. 2003. Age-dependent migration strategy in Honey Buzzards *Pernis apivorus* tracked by satellite. – Oikos 103(2): 385–396. DOI: 10.1034/j.1600-0706.2003.12145.x

Mellone, U., De la Puente, J., López-López, P., Liminana, R., Bermejo, A. & Urios, V. 2013. Migration routes and wintering areas of Booted Eagles *Aquila pennata* breeding in Spain. – Bird Study 60(3): 1–5. DOI: 10.1080/00063657.2013.781113

Meyburg, B-U., Ziesemer, F., Martens, H. D. & Meyburg, C. 2010. On the biology of the Honey Buzzard *(Pernis apivorus)*. Results of satellite tracking. – International Symposium "Population Ecology of Raptors and Owls". – Halberstadt, Germany. Poster 7.

Meyburg, B-U., Howey, P. W., Meyburg, C. & Fiuczynski, K. D. 2011. Two complete migration cycles of an adult Hobby tracked by satellite. – British Birds 104(1): 2–15.

Moreau, R. E. 1972. The Palearctic-African Bird Migration Systems. – Academic Press, London and New York

Niang, I., Ruppel, O. C., Abdrabo, M. A., Essel, A., Lennard, C., Padgham, J. & Urquhart, P. 2014. Africa. – In: Barros, V. R., Field, C. B., Dokken, D. J., Mastrandrea, M. D., Mach, K. J., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R. & White, L. L. (eds.) Climate Change 2014. Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. – Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1199–1265.

Phalan, B. 2010. Western Range DSO Iron Ore Project: Vol. 4, Part 1., Zoological Assessment. – Environmental and Social Impact Assessment (ESIA)/ Environmental and Social Management Plan (ESMP) for ArcelorMittal Liberia. URS/Scott Wilson, Basingstoke, Hampshire, UK

Strandberg, R., Klaassen, R. H. G., Hake, M., Olofsson, P. & Alerstam, T. 2008. Converging migration routes of Eurasian Hobbies *Falco subbuteo* crossing the African equatorial rain forest. – Proceeding Biological Science 276(1657): 727–733. DOI: 10.1098/rspb.2008.1202

Strandberg, R., Hake, M., Klaassen, R. H. G. & Alerstam, T. 2012. Movements of immature European Honey Buzzards *Pernis apivorus* in tropical Africa. – Ardea 100(2): 157–162. DOI: 10.5253/078.100.0207

Ornis Hungarica 2023. 31(1): 197–201.
DOI: 10.2478/orhu-2023-0013

A photographic record of partial leucism in Greater Coucal *Centropus sinensis* (Stephens, 1815) (Cuculiformes: Cuculidae) from Chhattisgarh, India

Mattathil Jacob ALBY, Cheruthottunkara Purushothaman ASHWIN & Moolumkudy Suresh ARJUN*

Received: December 01, 2022 – Revised: January 23, 2023 – Accepted: January 27, 2023

Alby, M. J., Ashwin, C. P. & Arjun, M. S. 2023. A photographic record of partial leucism in Greater Coucal *Centropus sinensis* (Stephens, 1815) (Cuculiformes: Cuculidae) from Chhattisgarh, India. – Ornis Hungarica 31(1): 197–201. DOI: 10.2478/orhu-2023-0013

Abstract Leucism is a colour anomaly defined by a lack of pigmentation, which may be partial or full in any individual. Although genetic and environmental factors contribute to a high incidence of plumage colour aberrations in wild birds, the true incidence of these aberrations in wild populations has been studied very less. The present report describes an instance of partial leucism in a Greater Coucal *(Centropus sinensis)* from Chhattisgarh, India. This colour aberration in this species was first documented in 1990. More research is needed to determine the exact reasons for the high incidence of partial leucism in wild birds, which might include nutrition, lifespan, behaviour, parasitism, or other environmental factors.

Keywords: colour aberrations, leucism, Greater Coucal, Chhattisgarh, India

Összefoglalás A leucizmus a pigmentáció hiányából következő színrendellenesség, amely egyedenként lehet részleges vagy teljes. A vadon élő madarak tollazati színrendellenességeinek nagy számú előfordulásához genetikai és környezeti tényezők is hozzájárulnak. Ezeknek a rendellenességeknek az előfordulását a vadon élő populációkban alig tanulmányozták. A jelen tanulmány az indiai Chhattisgarh-ban megfigyelt nagy bozótkakukk *(Centropus sinensis)* részleges leucizmusának egy esetét írja le. Ezt a színrendellenességet 1990-ben figyelték meg először a fajnál. A vadon élő madarak részleges leucizmusa okainak meghatározására, beleértve a táplálkozást, az élettartamot, a viselkedést, a parazitizmust vagy más környezeti tényezőket, további kutatásra van szükség.

Kulcsszavak: színrendellenesség, leucizmus, nagy bozótkakukk, Chhattisgarh, India

Salim Ali Centre for Ornithology and Natural History, Coimbatore – 641108, Tamil Nadu, India
** corresponding author, e-mail: arjunsuresh75@gmail.com*

Introduction

Birds rely on plumage colouration for concealment (Barragán-Faras *et al.* 2019), mate selection (Hill *et al.* 1999), social communication (Senar *et al.* 2006), and a variety of other behavioural and physiological functions. Colouration in birds is usually caused by pigments, nano- and macrostructure, or a combination of them (e.g. Laczi *et al.* 2019). Melanins and carotenoids are the primary pigments involved in bird colouration (e.g. LaFountain *et al.* 2015, Eliason *et al.* 2016). Furthermore, pigment-related colour abnormalities within a species are quite common in addition to differences in colour across species (Van Grouw

2006, 2013, McCardle 2012). It has been reported that wild-living birds exhibit several colour aberrations in their plumage or bare parts of their bodies. Among the mutations that have been observed, albinism (e.g. Laczi *et al*. 2019), leucism (e.g. Izquierdo *et al*. 2018), browns (e.g. Van Grouw *et al*. 2011), and diluted (e.g. Weidensaul *et al*. 2015) are the most frequently reported and most likely to occur. In the case of leucism, a particular pigment (e.g. eumelanin or pheomelanin) is completely absent in the entire plumage or selected feathers (Nemésio 1999, Van Grouw 2013). The majority of cases of leucism are caused by the expression of mutant alleles that prevent melanoblasts (early melanin pigment cells) migrating from the embryonic neural crest to the skin. This causes white feathers and pink skin where melanoblasts are missing (Bensch *et al.* 2000, Van Grouw 2014). In some cases, leucism can result from genetic disorders affecting melanin synthesis. Leucistic birds, in contrast to albino birds, have normal pigmentation in other parts of their bodies, such as their bills, eyes, and legs (Van Grouw 2006). The present study reports a partial leucism in Greater Coucal *Centropus sinensis* from Chhattisgarh, India.

Notes and Observations

On February 20, 2022, we saw an adult Greater Coucal with partial white feathers perching on an electric wire near the Kartala village (22°18'07.0"N 82°59'57.1"E; Elevation 286 MSL) in the Korba district of Chhattisgarh, India *(Figure 1)*. The recorded area was mostly farmlands and typically devoted to cultivating crops and rearing cattles. Additionally, the area is surrounded by sparse woody vegetation. The field observations and notes were made with Monarch (10×42) binoculars, and photos were taken with a Nikon P900 point-and-shoot camera. The identification key for colour aberrations provided by Mahabal *et al.* (2016) was used to name the feather aberration.

Greater Coucal is a large, non-parasitic member of the Cuculiformes with a long and hefty black tail, and intense red eyes. Both males and females are similar in appearance and they can grow up to 45–50 cm in length, including the tail. The wings and back are chestnut brown, while the underwing coverts are black. The juveniles seem considerably more subdued than the adults, with white bars on the tail and underparts, and varying degrees of black streaks on the wings and top parts. Greater Coucals resemble their smaller sister species, the Lesser Coucal *(Centropus bengalensis)*, but they are bigger and have a longer beak and bright red eyes. The adult Greater Coucal lacks the white stripes seen on the wings of the Lesser Coucal (Grimmett *et al.* 2011, Ebird 2022).

A case of partial leucism was recorded in a Greater Coucal from Chhattisgarh, India *(Figure 2)*. The individual was observed from a safe distance for about 10–15 minutes. The bird's feathers were partially unpigmented, with white patches on the dorsal side. Most of the primary and secondary wing feathers were fully white, with few partially coloured feathers. However, primary coverts, alula, lesser coverts, median coverts, greater secondary coverts and tertiary were normally coloured. A few tail feathers were also partially white. The bird was observed perching on an electric wire and vocalised normally. It was not an albino as it had normal coloured eyes and all its other features were inherent as a Greater Coucal, except for the dorsal body colour. Leucism can be distinguished from albinism

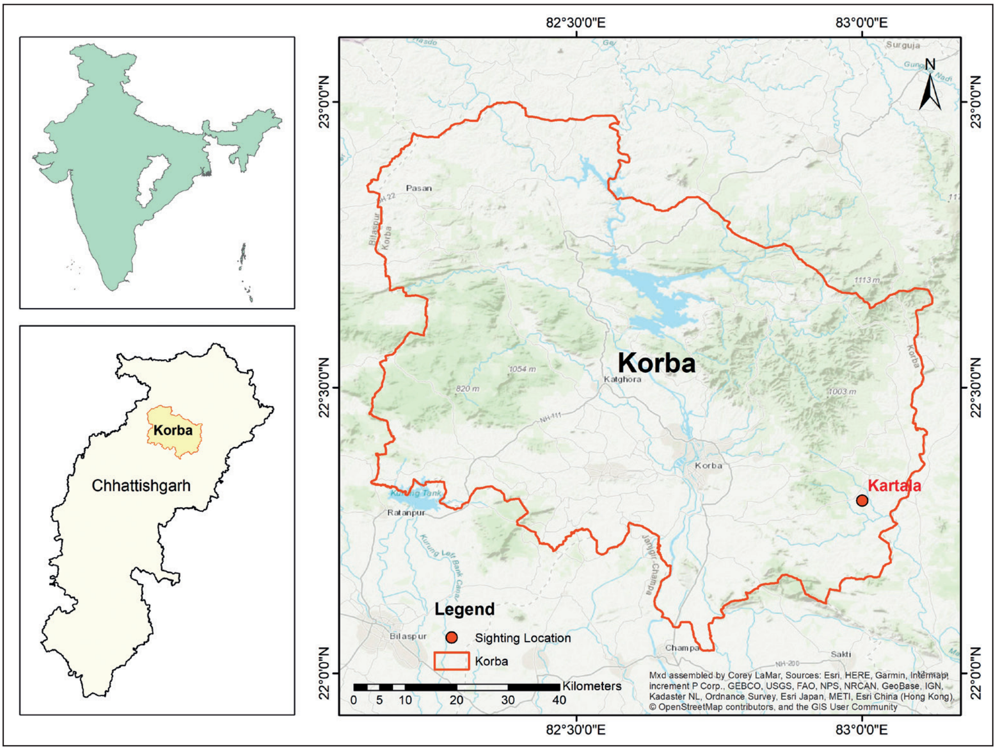


Figure 1. Map representing the recorded location of partial leucistic Greater Coucal
1. ábra A részlegesen leucisztikus nagy bozótkakukk megfigyelési helye

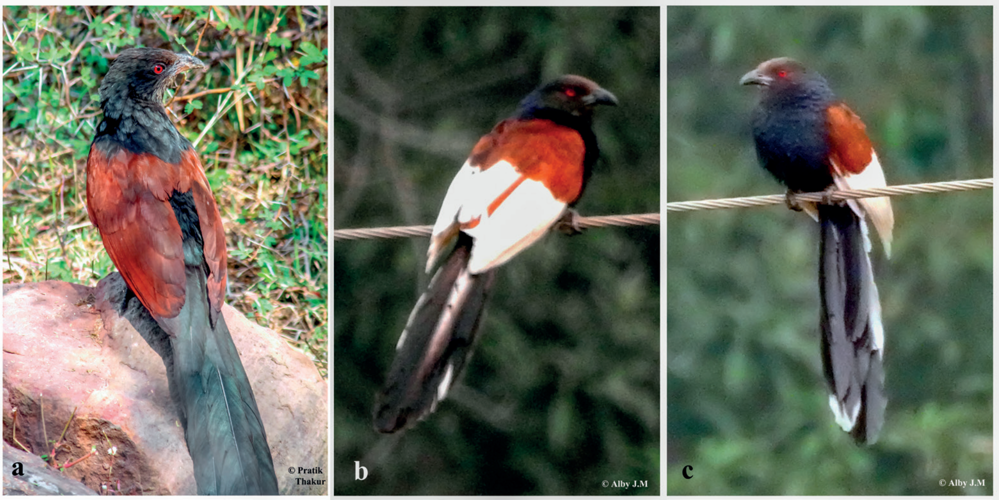


Figure 2. Photographs representing dorsal (b) and ventral (c) view of the recorded partial leucistic individual compared with a normal Greater Coucal (a)
2. ábra A részlegesen leucisztikus egyed hátoldali (b) és hasoldali (c) nézete egy normál színezetű nagy bozótkakukkhoz képest (a)

by the colour of the eyes and feathers as well as the bare parts of the bird. In leucism, the number of white feathers varies and the eyes are usually normal (Mahabal *et al.* 2016).

The occurrence of leucism and albinism can be influenced by environmental factors such as diet, age, disease, and chemical exposure like pesticides (Narayana *et al.* 2015). Among the chronicles of colour aberrations in Indian birds between 1886 and 2015 (Mahabal *et al.* 2016), there is only one case of partial leucism reported across the distribution range of the species in Uttar Pradesh (Ghosal & Ghose 1990). Some of the other bird species reported by leucism in India are Lesser Whistling Duck *Dendrocygna javanica* (Gayen *et al.* 2021), Indian Robin *Saxicoloides fulicatus* (Kasambe & Telkar 2021), Jungle Myna *Acridotheres fuscus* (Samal *et al.* 2021), Coppersmith Barbet *Psilopogon haemacephalus* (Gayen *et al.* 2022). The present study represents the first photographic report of partial leucism in a Greater Coucal from Chhattisgarh, India. Further research is required to determine the true causes of the high frequency of partial leucism detected in wild birds.

Acknowledgements

We are grateful to Dr. Bibhu Prasad Panda, Nandu Vijayakumar Sreelatha Devi and Pratik Thakur for their support during manuscript writing. The authors are also thankful to the reviewers for their valuable input in this manuscript.

References

Barragán-Farías, K. A., Pérez-Casanova, R. A., Galindo-Cruz, A., Hudon, J. & Rosas-Espinoza, V. C. 2019. Description of a xanthochroic House Finch *(Haemorhous mexicanus)* from Jalisco, Mexico. – The Wilson Journal of Ornithology 131(4): 850–855. DOI: 10.1676/1559-4491-131.4.850

Bensch, S., Hansson, B., Hasselquist, D. & Nielsen, B. 2000. Partial albinism in a semi-isolated population of Great Reed Warblers. – Hereditas 133(2): 167–170. DOI: 10.1111/j.1601-5223.2000.t01-1-00167.x

Ebird 2022. Greater Coucal. – https://ebird.org/species/grecou1/IN. Accessed November 25 2022

Eliason, C. M., Shawkey, M. D. & Clarke, J. A. 2016. Evolutionary shifts in the melanin-based color system of birds. – Evolution 70(2): 445–455. DOI: 10.1111/evo.12855

Gayen, D., Roy, S., Adhurya, S., Singhamahapatra, A., Seal, S. & Dutta, A. 2022. "Leucism resulting in xanthochroism" – A report on colour aberration in Coppersmith Barbet from Asia. – Ornis Hungarica 30(1): 69–79. DOI: 10.2478/orhu-2022-0005

Gayen, D., Saha, S. & Adhurya, S. 2021. Report of partially leucistic Lesser Whistling Duck from West Bengal, India. – Zoos' Print Journal 36: 31–33.

Ghosal, D. K. & Ghose, R. K. 1990. Partial albinism in a specimen of the Crow Pheasant, *Centropus sinensis sinensis* (Stephens). – Records of the Zoological Survey of India 87(4): 337.

Grimmett, R., Inskipp, C. & Inskipp, T. 2011. Birds of the Indian Subcontinent, 2nd ed. – London: Oxford University Press & Christopher Helm, pp. 1–528.

Hill, G. E., Nolan, P. M. & Stoehr, A. M. 1999. Pairing success relative to male plumage redness and pigment symmetry in the House Finch: temporal and geographic constancy. – Behavioral Ecology 10(1): 48–53. DOI: 10.1093/beheco/10.1.48

Izquierdo, L., Thomson, R. L., Aguirre, J. I., Díez-Fernández, A., Faivre, B., Figuerola, J. & Ibáñez-Álamo, J. D. 2018. Factors associated with leucism in the Common Blackbird *Turdus merula*. – Journal of Avian Biology 49(9): e01778

Kasambe, R. & Telkar, D. 2021. Sighting of a partially leucistic Indian Robin *Saxicoloides fulicatus* at Akola, Maharashtra, India. – Newsletter for Birdwatchers 54(3): 30–32.

Laczi, M., Hegyi, G., Kötél, D., Csizmadia, T., Lőw, P. & Török, J. 2019. Reflectance in relation to macro-and nanostructure in the crown feathers of the Great Tit *(Parus major)*. – Biological Journal of the Linnean Society 127(1): 113–124. DOI: 10.1093/biolinnean/blz016

Laczi, M., Herényi, M., Hegyi, G. & Török, J. 2019. First record of true albinism in a natural population of Collared Flycatchers *Ficedula albicollis*. – Ardea 107(3): 340–343. DOI: 10.5253/arde.v107i3.a8

LaFountain, A. M., Prum, R. O. & Frank, H. A. 2015. Diversity, physiology, and evolution of avian plumage carotenoids and the role of carotenoid–protein interactions in plumage color appearance. – Archives of Biochemistry and Biophysics 572: 201–212. DOI: 10.1016/j.abb.2015.01.016

Mahabal, A., Van Grouw, H., Sharma, R. M. & Thakur, S. 2016. How common is albinism really? Colour aberrations in Indian birds reviewed. – Dutch Birding 38: 301–309.

McCardle, H. 2012. Albinism in wild vertebrates. – MSc Thesis Texas State University, San Marcos, Texas, USA

Narayana, B. L., Surender, G. & Vasudeva, R. V. 2015. A note on deformities in the Rosy Starling *(Pastor roseus)*, Telangana, India. – TAPROBANICA: The Journal of Asian Biodiversity 7(4): 258–259.

Nemésio, A. 1999. Plumagens aberrantes em Psittacidae neotropicais-uma revisão [Aberrant plumage in neotropical Psittacidae-a review]. – Melopsittacus 2(2/4): 51–58. (in Portuguese)

Samal, A., Mishra, P. & Fullonton, S. 2021. First glimpse of a leucistic Jungle Myna from Odisha, India. – Entomology Ornithology Herpetology 10: 239.

Senar, J. C. 2006. Color displays as intrasexual signals of aggression and dominance. – In: Hill, G. E. & McGraw, K. J. (eds.) Bird Coloration Vol. II. Function and Evolution. – Cambridge: Harvard University Press, pp. 87–136. DOI: 10.2307/j.ctv22jnr8k.6

Van Grouw, H. 2006. Not every white bird is an albino: sense and nonsense about colour aberrations in birds. – Dutch Birding 28(2): 79–89.

Van Grouw, H. 2013. What colour is that bird. – British Birds 106: 17–29.

Van Grouw, H. 2014. Some black-and-white facts about the Faeroese White-speckled Common Raven *Corvus corax varius*. – Bulletin of the British Ornithologist's Club 134: 4–13.

Van Grouw, H., Russell, S. & Merne, O. J. 2011. Notes on colour aberrations in Common Guillemot *Uria aalge* and Northern Gannet *Morus bassanus*. – Seabird 24: 33–41.

Weidensaul, S., Stoffel, M., Monroe, M. S., Okines, D., Lane, B., Gregoire, J., Gregoire, S. & Kita, T. 2015. Plumage aberrations in Northern Saw-whet Owls *(Aegolius acadicus)*. – Journal of Raptor Research 49(1): 84–88. DOI: 10.3356/jrr-13-00073.1

Ornis Hungarica 2023. 31(1): 202–204.
DOI: 10.2478/orhu-2023-0014

First record of Brown-necked Raven *Corvus ruficollis* in Lebanon, 2022

Michel Sawan

Received: May 14, 2022 – Revised: February 21, 2023 – Accepted: February 22, 2023

Sawan, M. 2023. First record of Brown-necked Raven *Corvus ruficollis* in Lebanon, 2022. – Ornis Hungarica 31(1): 202–204. DOI: 10.2478/orhu-2023-0014

Abstract The Brown-necked Raven *(Corvus ruficollis)* has an extremely large distribution range in Africa and Asia, including the Middle East. The species primary live in deserts and semi-deserts, however its urban population is also increasing. In this paper, I reported the first record of the species for Lebanon. On 8th February 2022, I have seen an individual on the seaside coast near the harbor in Tripoli, North Lebanon. After I took photos of the bird, several ornithologist confirmed my correct identification. The nearest country where it was recorded before is Palestine.

Keywords: First Record, Brown-necked Raven, new species in Lebanon, *Corvus ruficollis*

Összefoglalás A barnanyakú holló *(Corvus ruficollis)* rendkívül nagy elterjedési területtel rendelkezik Afrikában és Ázsiában, beleértve a Közel-Keletet is. Elsősorban sivatagokban és félsivatagokban él, de az utóbbi időszakban városokban is megjelent fészkelőként. Ebben a közleményben a faj első libanoni megfigyeléséről írok. 2022. február 8-án az Észak-Libanonban található Tripoli kikötőjének közelében megfigyeltem egy példányt. A madárról bizonyítófotókat készítettem, majd ezeket elküldtem több ornitológusnak, akik megerősítették a határozás helyességét. Libanonhoz legközelebb korábban Palesztinában észlelték a fajt.

Kulcsszavak: első megfigyelés, barnanyakú holló, Libanon, *Corvus ruficollis*

e-mail: michelsawan@hotmail.com

The Brown-necked Raven *(Corvus ruficollis)* is a monotypic species with a wide distribution range across North Africa, the Middle East, the Arabian Peninsula, southern Iran and Central Asia (Walker 2009, Madge 2020). In some places its distribution range overlapping with the Common Raven *(Corvus corax)*, while in the south replacing it (Madge 2020).

The species is a primarily desert and semi-desert bird that avoids areas of cultivation (Madge 2020). Nesting sites can be in a variety of locations, but typically are on thorny trees (Jennings 1998, Shobrak 2005, Cunningham 2019).

It displays a great variety of foraging strategies as well as feeds on a variety of food items. The species' diet consists of rodents, snails, snakes, locusts and other grasshoppers, stranded fish (in coastal areas), grain, dates and other fruits (Belkacem *et al.* 2017, Madge 2020). There are also differences in the consumed food items between breeding and non-breeding seasons, while food waste of people such as pasta and chicken is also a significant part of the species's diet (Belkacem *et al.* 2017). Cooperative hunting on Egyptian Mastigure *(Uromastyx aegyptius)* in the Arava Valley, Israel was also observed which indicates the high intelligence of the Brown-necked Ravens (Yosef & Yosef 2010).

The Brown-necked Raven and Common Raven have both similarities and differences in their morphology. Therefore, for a clear field identification, they need to be carefully

observed in areas where both species occur. The Brown-necked Raven measures 48–56 cm in length and 103–120 wing spam. The head and throat are a distinct brownish-black, while the rest of the plumage is black glossed with purple, blue or purplish-blue. The feathers of this species often fade quite quickly to a brownish black or true black, and it can look distinctly brown by the time it moults. It flies with the bill pointing downward, and not uncommonly has less obviously wedge-shape to tail-tip, but these features do not always hold, or are hard to make out. At closest range it may show bronze-brown color on nape. The feet, legs and bill are black. It is larger than the Carrion Crow, but not as large as the Common Raven (Svensson *et al.* 2009).

The population is estimated to be increasing following increases owing to urban development, therefore the species is considered Least Concern conservation biological status (BirdLife International 2023).

On 8th of February 2022, I was birdwatching on the seaside coast near the harbor in Tripoli, North Lebanon, when I heard a bird screeching. The sound was not usual to me. It was coming from afar, near a ship that was emptying its cargo. The bird was attacked by some Yellow-legged Gulls *(Larus michahellis)* and then it went to join the Hooded Crows *(Corvus cornix)* that had rejected it in another fight. The bird's color was dark black at the first sight, I thought it was a Common Raven but its sound was different than that of a Common Raven and that is what drove me to chase it. I tried to take some photos but it was very far from me. I was able to take 5 shots only before it fled the area towards the deck of a big ship. After I went back home, and downloaded the photos, I noticed that this bird was not a Common Raven. It had a brownish color on the neck, a fan shape tail and a slimmer bill than the common crow. Analyzing all the data of what I have heard and seen, it turned out to be a Brown-necked Raven. I sent the photos to many experts from Europe who had to consult their friends from Israel, because they see it frequently there since it's a local breeding bird there. The confirmation came from Eilat Bird Watching Center (IBRCE) through Mr. Richard Prior that this was indeed a Brown-necked Raven, matching with two other ornithologists. The following day, I went to the same location, and sadly, there were 3 poachers on the place who had killed lots of seagulls and waders and many other birds. The Brown-necked Raven did not show up again there.

From nearby countries, the species was recorded recently in Turkey (Jakobsen 2016) and Cyprus (Howard & Howard 2018). I have two theories that made it appear in Lebanon on the north coast. The first one is that it might have come on the deck of a transportation ship and landed here before it disappeared the next day maybe due to poaching or perhaps it found its way out on the deck of a ship as well. The second theory is that it might have arrived to the area as it did in Cyprus by expanding its range of distribution. The species breeds in Israel (Madge 2020), therefore it is possible that the observed individual was originated from those population.

References

Belkacem, M., Marniche, F., Berrabah, D. E., Medina, F. M., Daoudi-Hacini, S. & Doumandji, S. 2017. Scavenging diet of Brown-necked Raven *Corvus ruficollis* Lesson, 1830 (Aves: Corvidae) in a hyper-arid region of Central Algerian Sahara. – Acta Zoologica Bulgarica 69(2): 239–248.

BirdLife International 2023. Species factsheet: *Corvus ruficollis*. – http://www.birdlife.org on 10/02/2023

Cunningham, P. 2009. Nesting tree utilisation by Brown-necked Ravens *Corvus ruficollis* in west central Saudi Arabia. – Sandgrouse 31: 68–72.

Howard, K. & Howard, R. 2018. First record of Brown-necked Raven *Corvus ruficollis* for Cyprus. – Cyprus Bird Report 2016: 169 and Plate 27.

Jakobsen, O. 2016. Occurrence of the Brown-necked Raven, *Corvus ruficollis*, at Cizre in Eastern Turkey. – Zoology in the Middle East 1(1): 32–33.

Jennings, M. C. 1998. Brown-necked Raven, *Corvus ruficollis*. – Phoenix 15: 18–19.

Madge, S. 2020. Brown-necked Raven *(Corvus ruficollis)*, version 1.0. – In: del Hoyo, J., Elliott, A., Sargatal, J., Christie, D. A. & de Juana, E. (eds.) Birds of the World. – Cornell Lab of Ornithology, Ithaca, NY, USA. DOI: 10.2173/bow.brnrav1.01

Shobrak, M. 2005. Breeding success of Brown-necked Ravens *Corvus ruficollis* in the Mahazat as-Sayd Protected Area, Saudi Arabia. – Sandgrouse 27: 152–157.

Svensson, L., Mullarney, K., Zetterström, D. & Grant, P. 2009. Collins Bird Guide. 2nd ed. – Harper Collins, London

Walker, M. 2009. Clever ravens cooperatively hunt. – BBC Earthnews website. British Broadcasting Corporation

Yosef, R. & Yosef, N. 2010. Cooperative hunting in Brown-necked Raven *(Corvus rufficollis)* on Egyptian Mastigure *(Uromastyx aegyptius)*. – Journal of Ethology 28: 385–388. DOI: 10.1007/s10164-009-0191-7