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Multi-species settlement by secondary hollow-nesting passerine birds in a European Bee-eater *(Merops apiaster)* colony

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Abstract Simultaneous nesting of six species of secondary hollow-nesting passerine birds in abandoned European Bee-eater *Merops apiaster* nest-holes has been detected and described. The holes were occupied by Great Tit *Parus major*, Spotted Flycatcher *Muscicapa striata*, European Pied Flycatcher *Ficedula hypoleuca*, Black Redstart *Phoenicurus ochruros*, Eurasian Tree Sparrow *Passer montanus* and White Wagtail *Motacilla alba*, which formed a multi-species settlement in a European Bee-eater colony.

Keywords: *Merops apiaster, Parus major, Phoenicurus ochruros, Ficedula hypoleuca, Muscicapa striata, Passer montanus,* nest holes

Összefoglalás A gyurgyalag *(Merops apiaster)* régi odúiban hat másodlagosan üregben fészkelő madárfaj egyidejű fészkelését írták le: széncinege *(Parus major)*, szürke légykapó *(Muscicapa striata)*, kormos légykapó *(Ficedula hypoleuca)*, házi rozsdafarkú *(Phoenicurus ochruros)*, mezei veréb *(Passer montanus)* és barázdabillegető *(Motacilla alba)*, amelyek egy többfajos közösséget alkottak egy gyurgyalag telepen.

Kulcsszavak: széncinege, házi rozsdafarkú, kormos légykapó, szürke légykapó, mezei veréb, odúk

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Introduction

The European Bee-eater *Merops apiaster* is recognized as an effective ecosystem engineer (Casas-Criville & Valera 2005, Sekercioglu 2006, Gyurácz *et al*. 2013, Smalley *et al*. 2013), i.e. a species that creates, modifies, or maintains a habitat, creates changes in the state of biotic and abiotic conditions that directly or indirectly affect the availability of resources for other species (Jones *et al*. 1997, Wilby 2002). Namely, European Bee-eater nest holes are utilized by other bird species for nesting that are unable to dig nest holes in banks, andvertical walls of outcrops.

Birds build nests to keep and protect eggs and chicks, to provide optimal humidity and temperature conditions necessary for the development of embryos and chicks (Heneberg

& Simecek 2004, Deeming 2016, Kristofik *et al*. 2017). Nests of different species vary significantly, and the structure of the nest is species-specific (Biddle *et al*. 2018). However, several patterns can be detected (Nagy *et al*. 2019). Intraspecific variation of nests in terms of location, size, and composition of building material has been described (Britt & Deeming 2011, Briggs & Deeming 2016, Biddle *et al*. 2018).

Many species of birds use closed nests made by other animals such as the European Bee-eater. Therefore a mixed-species breeding association of birds is formed in European Bee-eater colonies. The use European Bee-eater nest-holes by Common Kestrel *Falco tinnunculus*, Little Owl *Athene noctua*, Common Swift *Apus apus*, Eurasian Wryneck *Jynx torquilla*, European Roller *Coracius garrulus*, Eurasian Hoopoe *Upupa epops*, Northern Wheatear *Oenanthe oenanthe*, Common Starling *Sturnus vulgaris*, Eurasian Tree Sparrow *Passer montanus*, and House Sparrow *Passer domesticus* has been previously recorded (Shupova 1999, Malovichko & Konstantinov 2000, Gyurácz *et al*. 2013, Urban *et al*. 2013). Birds find protection from predators and bad weather conditions in European Bee-eater burrows, (Gyurácz *et al*. 2013). Recently, the list of birds inhabiting Bee-eater holes has been expanded. It is described that Coal Tit *Periparus ater* (Klitin 1972), Eurasian Blue Tit *Cyanistes caeruleus* (Buchko & Skilskiy 1995), Great Tit *Parus major* (Belik 1999, Shupova & Chaplygina 2017), Collared Flycatcher *Ficedula albicollis* (Knysh & Savinskaya 2013) also nests in European Bee-eater burrows. These bird species might try to find secure nesting sites or reduce rivalry with other hole-nesters (von Haartman 1957).

The purpose of ouris study is to analyze the species composition of hollow-nesting passerine birds that inhabited burrows, forming a poly-species settlement in one of the colonies of European Bee-eater.

Materials and Methods

We found a multi-species nesting settlement of birds in the vertical walls of the main parent outcrops on the Khotiv village Kyiv region. It is located directly on the outskirts of the residential zone of a settlement, and was established in a European Bee-eater colony existing for several years. The territory is part of the Kyiv plateau, belongs to the north of the forest-steppe zone and is located at the northern border of the European Bee-eater nesting area in Ukraine (50°19’18.6”N 30°29’40.3”E). The climate is moderately continental with warm summers and mild winters. Recent studies have noted a warming trend in the region (Netsvetov *et al*. 2018). The average annual temperature is 7.5 °C, the average temperature in July is 19.8 °C. Average annual precipitation is 606 mm with a maximum in July (75 mm).

We found the nesting settlement on 05th on July 2018. Observations were carried out in 2019 (06 May; 12 June; 09 July), 2020 (04 May; 03 June; 02 July; 16 July) and 2021 (04 May; 15 June; 06 July; 22 July). The discovered burrows were mapped with a brief description of the biotope, the location of the nest; and photographic recording of observations were taken. The reproductive cycle stage (incubation, feeding of chicks) was established via visual observation and was based on observation, and were categorized the number of birds leaving the nest, arriving to the nest with food, and other characteristics of bird behavior.

Results

The multi-species colony is separated from the human settlement by a dirt road, bordered by a meadow and a forest. The nests are located in a steep wall of a natural ravine. The cliff is composed of soft rocks, there are layers of loess, loams, clays, sandstones. The surface of the ravine is a dry meadow presence dominance of bushgrass *Calamagrostis epigeios*, common agrimony *Agrimonia eupatoria*, narrow-leaved meadow-grass *Poa angustifolia* and with young European aspen *Populus tremula*, silver birch *Betula pendula*, Scots pine *Pinus sylvestris*, boxelder *Acer negundo*, European dewberry *Rubus caesius*, common dogwood *Cornus sanguinea* was recorded. The total length of the ravine is 143 m, the length of the wall free from vegetation is about 35 m, and the height is 7 m, in the left part it is vertically divided into two ledges. The European Bee-eater is the dominant species here, but thethe number of occupied nests was quitebreeding pairs is low during the study period. The number of occupied burrows were: nine burrows in 2018, five in 2019, six in 2020, four in 2021.

European Bee-eaters dig their nests choose those parts of the cliff for nesting that are not covered by vegetation. The destruction of the cliff wall after rains is often observed. Often European Bee-eaters dug burrows in the central and upper part of freshly collapsed wall. The height of burrows on all colonys in the vicinity of Kyiv is 90–580 cm (on average,

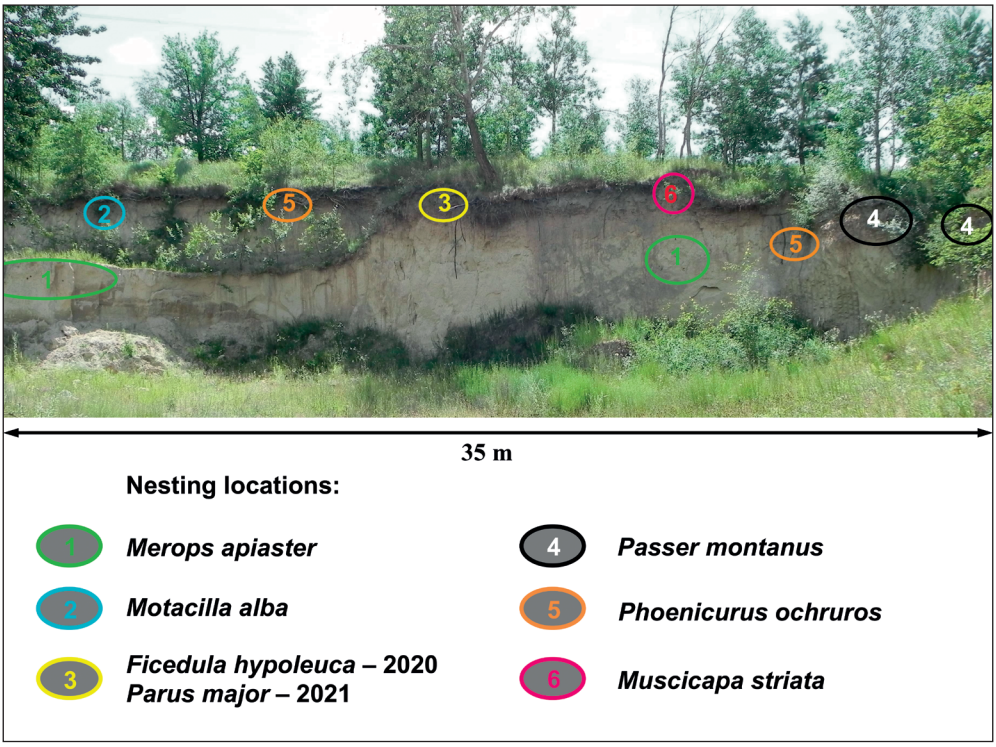

Figure 1. Distribution of species on nesting in burrows in a multi-species settlement
1. ábra A különböző fajok fészkeinek elhelyezkedése a fészektelepen

213.86±15.88; CV=48%; n=42). In this described colony, European Bee-eater burrows (n=27; 2018–2021) were located at an altitude of 90–400 cm (on average 200.1±8.81; CV=23%). The diameter of the European Bee-eater burrows is 5.5–6.5 cm (on average 6.08±0.12; CV=7%).

Seven species of secondary hollow-nesting birds settled in the burrows of the European Bee-eater, in different years: in 2018 – one pair of Common Starling and five pairs of Eurasian Tree Sparrow; in 2019 – one pair of Great Tit and four pairs of Eurasian Tree Sparrow.

The richest years regarding species composition of the colony were 2020 and 2021 *(Figure 1)*. On 16 July 2020, we observed here, simultaneously with nesting European Bee-eater, two pairs of Black Redstart *Phoenicurus ochruros*, one pair of European Pied Flycatcher *Ficedula hypoleuca*, one pair of Spotted Flycatcher *Muscicapa striata*, and four pairs of Eurasian Tree Sparrow. European Bee-eater, Eurasian Tree Sparrow, European Pied Flycatcher, Spotted Flycatcher, one pair of Black Redstart fed chicks in burrows. Adults of the second pair of Black Redstart and four juveniles were feeding together near the cliff. Black Redstart females periodically clashed with each other and with the flying male Barn Swallow *Hirundo rustica*.

Secondary hollow-nesters occupied old burrows at a height of 2 m or higher *(Table 1)*. Spotted Flycatcher, European Pied Flycatchers and Great Tit settled at the highest. All species chose burrows, next to which, not far from the entrance, there were roots or branches of woody plants. Birds used them to outlook posts, stopped on them before entering a burrow, to look out for insects, or for long duration observation. The diameter of the burrow entrance inhabited by passerine birds was also significantly larger than the diameter of the European Bee-eater burrows. This indicates that the secondary hollow-nesting birds (with the exception of Tree Sparrow) occupy very old burrows, partially destroyed and do not create competition for the European Bee-eater. The Tree Sparrow is less capricious, settles in different burrows.

In this ravine, the burrows occupied by Black Redstart are located at a distance of about 20 m, but they are not in the line of sight. This is prevented by the bend of the ravine and

Table 1. Parameters of burrows occupied by Passeriformes Note: H – distance from the nest to the top edge of the cliff; h – distance from the nest to the bottom edge of the cliff; D – diameter of the tunnel entrance

1. táblázat Az énekesmadár fajok által elfoglalt költőüregek paraméterei. H – a fészek és a fal felső szélének távolsága, h – a fészek és a fal alsó szélének távolsága, D – az üreg bejáratának átmérője

Species	h (m)	H (m)	D (cm)
Motacilla alba	2.0	0.1	7.5
Ficedula hypoleuca	5.0	0.4	11.0
Muscicapa striata	6.0	0.1	7.0
Phoenicurus ochruros	3.0–3.50	0.40–1.0	8.0–10.0
Parus major	5.0	0.40	11.0
Passer montanus	2.0–2.10–2.20–3.50	0.25–0.25–0.50–1.0	5.5–5.5–6.0–7.0

the growth of young European aspen on the ledge. In 2021, Black Redstart settled in the same burrows as in 2020; on 06 June 2021, both pairs fed chicks in the nests, the males periodically vocalised. On 22 July 2021, after heavy rainfall, the ravine wall collapsed in several places. The burrows in which the Black Redstart nested partially survived, but we did not observe any birds. The height of the burrows occupied by Black Redstart is 3–3.5 m from the base of the cliff, and the distance to the upper edge of the cliff was 0.4 to 1.0 m. One burrow was located on the upper ledge of the ravine and was hidden by European aspen, the second was located in the high part of the ravine, but was also covered with separate tree branches. Before visiting the burrow, birds landed on the branches of fallen or living tree.

Eurasian Tree Sparrows settled in an aggregated manner in the left part of the ravine, hidden by tree branches. Burrows here are almost destroyed; the height of the wall is about 1–1.5 m, in some places the wall of the cliff is overgrown with herbaceous vegetation. The number of breeding pairs decreased from five to one pair from 2018 to 2021. A possible reason for this may be that after the collapse of the ravine wall as a result of heavy rainfall, several European Bee-eater nests were destroyed, and they reconstructed two of the old burrows in the part of the ravine where the Eurasian Tree Sparrow nested. Eurasian Tree Sparrow were deprived of nest sites or nesting opportunities.

Previously suspected nesting of White Wagtail *Motacilla alba* was confirmed in 2021, when a Eurasian Sparrowhawk *Accipiter nisus* showed up at the colony. The first alarm signal was given by the European Bee-eater, reacting to which, all the birds united to expel the hawk. White Wagtail was found in the left part of the ravine above the ledge at a distance of less than 10 m from the Black Redstart nest.

Spotted Flycatcher and European Pied Flycatcher nested in cliff burrows only in 2020, in the upper part on the border with the soil layer under the hanging plant roots. In 2021, the nesting site of European Pied Flycatcher was taken by a Great Tit pair. These burrows are very old, washed out and deformed by soil erosion.

Discussion

European Bee-eaters used the same burrows for several years (Shupova 1999, Bastian *et al.* 2013). By re-using existing nesting burrows they might potentially save time and energy, and can allocate it layingto other activities during the laying period (Brust *et al.* 2015). 22–54% of European Bee-eaters have used the same cliff for nesting several times, and in 26% of the breedings the same burrows were chosen by the same pair (Brust *et al.* 2015). The use of hollows several times was also noted for hollow-nesters. It is also known that the same holes might be used consecutively by different bird species (Wesołowski 1989) As the cliff becomes overgrown and it becomes difficult to enter the burrow, European Bee-eaters leave old burrows and dig new ones. Urbán *et al.* (2013) believe that thickets of woody vegetation in front of burrows prevent birds from flying in and out of the burrow. The height of the European Bee-eater burrows is very variable and depends on the height of the cliffs in the region. For example, in the steppe zone of Ukraine, the height of the European Bee-eater

burrows, on average 315.70 cm, and the distance to the upper edge of the cliff is 81.80 cm (Shupova 1999).

The Great Tit nests in hollows, artificial nests, crevices of various buildings, cracks in rocks, cavities under tree roots. It is suggested that the noted feature of the ecology of the genus *Parus* is associated with their evolution in mountainous landscapes. Then, settling on the plains, tits switched to a forest lifestyle, but retained a high plasticity of their nest-building instincts (Belik 2009). Nesting of Great Tit in European Bee-eater burrows has already become a common occurrence in the steppe (Belik 1999, Shupova & Chaplygina 2017).

In flat landscapes of Ukraine Black Redstart subspecies *Ph. o. gibraltariensis* behaves like a synanthrope and nests, as a rule, in human structures (Knysh 2013, Shupova 2014), old nests of Barn Swallows (Monteagudo 1999, Knysh 2013). There is a known case of joint nesting of Common House Martin *Delichon urbicum* and Black Redstart in the Common House Martin nest (Krynski 2017). In Tibet, birds of the subspecies *Ph. o. phoenicuroides* tend to nest in burrows created by other animals (Chen *et al.* 2011, Lu *et al.* 2011). Perhaps we are witnessing the next stage of adaptation of the *Ph. o. gibraltariensis* to the conditions of habitation of the secondary area, they start nesting outside the urbanized biotopes, where the resource of nesting sites is exhausted, and the naturalisation of the species in the forest-steppe zone of Ukraine in the absence of rocks. At the same time, the birds follow the skills of a related subspecies, nesting in the clay walls of cliffs.

It should be noted that earlier, in the biotopes of the residential zone, we already observed a conflict between Black Redstart females, and, most likely, this is normal for the species. In the residential area, we determined the closest location of the nests of this species – 100 m (Shupova 2018).

For 10 years, we have been recording the nesting of White Wagtail and Black Redstart under the roof of the same building in the territory of the Feofania Park and have never observed a conflict between them. White Wagtail is a species that for a long period has been characterized by nesting in cavities among bare tree roots in cliffs of river and lake banks, in grooves of sandy cliffs, in forest ravines recess, and in burrows of birds and rodents (Chaplygina 2014).

Muscicapidae species are characterised by high flexibility in the selection of nesting sites and use a wide range of nesting locations. The previously described Spotted Flycatcher positions are shallow niches: hollows, rotted tree and branch breaks, old woodpecker hollows, Common Blackbird and Barn Swallow nests, divarication of branches, niches in human structures, artificial nests (Stoate & Szczur 2006). European Pied Flycatcher nests mainly in tree holes and artificial nests. European Pied Flycatcher nests in clear tree hollows free of parasites (Wesołowski 2000). The lack of clean hollows may have forced the pair to settle in the old European Bee-eater burrow, which has not been used for a long time.

Eurasian Tree Sparrow is known to use the European Bee-eater burrows for nesting (Shupova 1999, Gyurácz *et al.* 2013, Stubbe *et al*. 2016). It is described that Eurasian Tree Sparrow often visit European Bee-eater burrows during their absence, clog them with stems and leaves of herbaceous vegetation, fluff and other bulky material, and make

a spherical nest inside the burrows (Malovichko & Konstantinov 2000). European Bee-eaters are aggressive towards sparrows trying to settle in the colony, therefore Eurasian Tree Sparrows nest on the periphery of the colony in the old part left by Bee-eaters.

When building nests, birds select materials and conditions according to genetically established criteria (Briggs *et al.* 2019). At the same time, nest building is a plastic behavior. Individual experiences allow birds to build different nests, resulting in geographic differences in the used building material and where they are located (Briggs *et al*. 2019, Mainwaring *et al.* 2021). The lack of free nesting sites on the territory of tree plantations can also stimulate nesting in burrows of hollow nests. Wesołowski (1989) argued that competition for holes in natural forests is less intense than in plantations. It was also shown that the combined density of secondary hole-nesting birds did not decrease when hollows were blocked in an experiment (Waters *et al*. 1990). Birds can adapt to new conditions in a changing environment (Mänd *et al*. 2005). In landscapes with a shortage of woody plants, and, accordingly, hollows, nesting in burrows gives birds the opportunity to colonize new territories and may result in population number increase or even enlargement of the species range.

The number of breeding European Bee-eater pairs in the region is highly variable. From 2018 to 2020 it steadily decreased not only in the described colony, but also in the neighbouring one: three pairs in 2018 and in 2019, two pairs in 2020. In 2021, the number of nesting burrows of European Bee-eater has increased to four here. The weather conditions of the region are not optimal for the breeding of this species, often at the beginning of summer there are prolonged rains. It was shown that the existence of European Bee-eater populations depends on changes in weather and climatic conditions in the area of the colony, especially at the northern borders of the species range (Arbeiter *et al*. 2016). Long periods of rains with low temperatures might force the birds to start nesting several weeks later (Bastian *et al*. 2011). In the vicinity of Kyiv, European Bee-eaters begin nesting after the rains stop and a sufficient number of insects appear to provide an opportunity to feed their offspring. The destruction of the cliff wall as a result of landslides after rains is often observed, accompanied by the loss of clutches. For example in 2021, part of the ravine on the outskirts of the village collapsed along with nesting burrows. We associate the increase in the number of nesting birds in the neighbouring colony with the fact that couples migrated here, whose nests were destroyed in the first colony. The surface of the soil above this cliff has a slope towards the opposite wall of the cliff, so it is not washed out by rains.

Observations of the European Bee-eater nesting in the vicinity of Kyiv show that the noticed increase in the species range in the last 25 years (Essel *et al*. 2016, Stubbe *et al*. 2016, Cattaneo 2018, Yankevich *et al*. 2018, Londei 2020) does not lead to an increase in the number of birds in the forest-steppe zone, the conditions of which remain extreme for the European Bee-eater.

Thus, the European Bee-eater behavior acts as a pioneer species, reclaiming fresh cliffs in the outcrops of the main parent rocks; and as ecosystem engineer species: its old nests are the nucleus of the multi-species settlements formationstations for birds setting up closed nests. We think that the identified cases of Spotted Flycatchers, European Pied Flycatchers and

Great Tits breeding in burrows are indicate a tendency for dendrophils nesting in hollows, and they explore new nesting biotopes because of the lack of trees. This process is caused by a decrease in the area of tree plantations, an increase in urbanised areas, the use of new construction, communication technologies and the changing species composition of plants. Species with plasticity in nest-building behavior inhabit new biotopes and landscapes. The adaptation of secondary hollow-nesting birds to nesting in burrows facilitates their settling in arid regions, where there has always been a shortage of large trees with hollows. As a consequence, the development of new territories will lead to the expansion of the nesting areas of more adaptable species. For Black Redstart, Common Starling, House Sparrow that evolved in mountainous landscapes, the way of nesting in burrows is close to species-specific (in cracks of rocks). In terms of nesting and feeding style, the biotopes of cliffs are also more similar to rocks than to forest biotopes. Thus, the colonisation of burrows with these birds should be regarded as a logical choice by birds of not only species-specific nesting sites, but also habitats that are close to species-specific.

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