

The diet of the European Bee-eater (*Merops apiaster*) in Višnjička Kosa, Belgrade, Serbia

Vuk POPIĆ^{1,2}, Jovana BILA DUBAIĆ², Aleksandar ČETKOVIĆ² & Ivana NOVČIĆ^{2*}

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Abstract We examined the diet of the European Bee-eater (*Merops apiaster*) within a suburban colony in Belgrade (Serbia). From 68 pellets, we identified 1236 prey individuals. The predominant prey was the Honey Bee (*Apis mellifera*), representing 59.0% of all extracted prey individuals, followed by ants (11.4%), bumble bees (*Bombus* spp.) (9.3%), other bees (8.6%), diverse other hymenopteran taxa (5.3%), coleopterans (3.4%), and dragonflies (1.5%). Honey bees and other bee taxa were present in the diet of bee-eaters significantly more in May than in June, while the opposite was true for other prey categories. This diet composition may be a result of local prey availability and the selective choice of prey categories during the chick provisioning period.

Keywords: Honey Bee, Hymenoptera, insectivorous birds, prey composition

Összefoglalás A gyurgyalag (*Merops apiaster*) táplálékválasztását vizsgáltuk Belgrád egyik külvárosi területén található költőtelepen. A 68 köpetből 1236 zsákmányállat-egyedet azonosítottunk. A házi méh (*Apis mellifera*) volt a leggyakoribb zsákmány, amely az összes egyed 59,0%-át tette ki. Ezt követték a hangyák (11,4%), poszméhek (9,3%), egyéb méhek (8,6%), egyéb hártýásszárnyúak (5,3%), bogarak (3,4%) és a szitakötők (1,5%). A házi méh és más méhtaxonok szignifikánsan nagyobb arányban voltak jelen a gyurgyalagok étrendjében májusban, mint júniusban. A többi zsákmányállat esetében ennek ellenkezőjét állapítottuk meg. A helyi, fiókanevelés idején jellemző táplálék-összetétel a költőtelep környékén élő zsákmányállatok elérhetőségének és a gyurgyalagok szelektív táplálékválasztásának lehetett az eredménye.

Kulcsszavak: házi méh, Hymenoptera, rovarévő madarak, zsákmányösszetétel

¹ Natural History Museum, Njegoševa 51, 11000 Belgrade, Serbia

² University of Belgrade – Faculty of Biology, Studentski trg 16, 11000 Belgrade, Serbia

* corresponding author, e-mail: inovcic@bio.bg.ac.rs

Introduction

Many birds rely on insects as important prey – around 60% of avian species worldwide, to a certain extent, depend on insects in their diet (Morse 1971). The loss of insect biomass, documented over the last couple of decades (Hallmann *et al.* 2017, Wagner 2020), has thus negatively affected populations of insectivorous birds on a global scale (Bowler *et al.* 2019, Spiller & Dettmers 2019, Møller *et al.* 2021). For example, populations of insectivorous birds in Europe declined by 13% from 1990 to 2015, while populations of omnivorous species remained stable over the same period (Bowler *et al.* 2019). Similarly, terrestrial insectivorous birds declined by 2.9 billion individuals across North America over the last

50 years, whereas population abundances of species in which insects are not principal prey have increased (Tallamy & Shriver 2021). Since the reproductive success of birds depends not only on food availability but also on prey type (Tallamy & Shriver 2021), detailed knowledge of prey composition and dietary preferences of insectivorous species is necessary for the planning and implementation of future conservation strategies.

Here, we examined the diet of an insectivorous bird, the European Bee-eater (*Merops apiaster*) (hereafter “bee-eater”), within a suburban colony in Belgrade, Serbia. The bee-eater is a long-distance migrant with a breeding range across Europe, Asia, the Mediterranean, and southern Africa. It winters in western, central, and southern Africa (Bastian & Bastian 2024). Its population in Serbia is estimated at 5,200–8,500 breeding pairs, with a stable short-term trend and an increasing long-term trend (BirdLife International 2021). The bee-eater is an obligate insectivore that captures its prey in flight (Bastian & Bastian 2024). While hymenopterans are its most common prey, the bee-eater is an opportunistic forager whose diet varies regionally and seasonally (Cramp 1985, Bastian & Bastian 2024). As the diet of the bee-eater has never been studied in Serbia, the information presented in this study contributes to the understanding of this species within the European part of its range.

Methods

The study was conducted in Višnjička Kosa, a suburban area of Belgrade, Serbia, in 2021. The study area is characterized by a mosaic of agricultural and ruderal habitats, forests, thickets, and hedgerows, with steep, bare loess slopes originating from past clay excavation (Jakovljević *et al.* 2008). Around 300 pairs of bee-eaters breed here, in a 500-meter-long bank with a height of 2–8 meters, in a mixed colony with Starlings (*Sturnus vulgaris*) and Common Swifts (*Apus apus*) (Raković *et al.* 2024).

We investigated the bee-eaters’ diet by analyzing their pellets, which were collected near the colony, typically under perches that the birds used for hunting and resting. Since the pellets were gathered along a 200-meter stretch of the bank containing over 100 active bee-eater nests, we assume that the sampled pellets reflect the diet of a representative number of individuals. We conducted pellet sampling in 18, 21 and 23 May and 7, 19 and 23 June 2021. Samples were stored at below -15 °C, and before analysis, pellets were submerged in a mixture of warm water and alcohol to facilitate the safe extraction of undigested prey remains. Remains of hymenopterans were typically identified to family or genus level, based on forewing size, shape, and distinctive details of wing venation. We quantified prey based on the number of extracted forewings, rounding to the nearest whole number if necessary. For the identification of Hymenoptera, we used keys to various aculeate subgroups, focusing on bee genera (Scheuchl 2000, Macek *et al.* 2010), and compared the material with the extensive collection of the Centre for Bee Research at the Faculty of Biology. Identification of the other insect orders (Hemiptera, Diptera, Odonata and Coleoptera) was primarily conducted at a coarser taxonomic level, for which we used general entomological guides (Chinery 1993, Brock 2017).

Table 1. Diet composition of European Bee-eaters: number of prey items consumed in May and June, the total number of prey items, and frequency of occurrence of prey taxa in bee-eaters' pellets

1. táblázat A gyurgyalagok táplálék-összetétele: a májusban és júniusban elfogyasztott zsákmányállatok száma, a zsákmányállatok teljes száma és a taxonok előfordulásának gyakorisága a köpetekben

Prey taxa	Number of prey items in May	Number of prey items in June	Number of prey items	Frequency of occurrence
Hymenoptera	738	420	1158	100%
Apoidea: Apidae – apid bees	599	274	873	94.1%
<i>Apis</i>	551	179	730	86.8%
<i>Bombus</i>	30	85	115	52.9%
Solitary nonparasitic Apidae (mostly <i>Eucera</i> and <i>Anthophora</i>)	11	9	20	17.6%
Solitary parasitic Apidae (mostly <i>Nomada</i>)	7	1	8	8.8%
Apoidea – other bees	62	16	78	36.8%
Andrenidae: <i>Andrena</i>	43	8	51	32.4%
Colletidae: <i>Colletes</i>	8	3	11	10.3%
Halictidae: mostly <i>Halictus</i> and <i>Lasioglossum</i>	10	1	11	8.8%
Melittidae: <i>Dasygaster</i>	0	4	4	2.9%
Megachilidae	1	0	1	1.5%
Ants and wasps	77	130	207	61.8%
Formicidae	48	93	141	33.8%
Apoidea – spheciform wasps	8	19	27	22%
Ichneumonidae	11	9	20	22%
Vespidae	10	8	18	22%
Scolidae (<i>Scolia</i>)	0	1	1	1.5%
Other insect orders	27	51	78	52.9%
Coleoptera	15	27	42	36.8%
Odonata	2	16	18	22%
Diptera	9	5	14	19.1%
Hemiptera	1	3	4	2.9%

For each prey category, we calculated the frequency of occurrence in the pellets and the proportion of total prey individuals (*Table 1*). Differences among prey categories were examined using binomial tests for proportions (Crawley 2013), applied to the major prey groups – Honey Bee (*Apis mellifera*), other hymenopterans and other insects – with Bonferroni adjustments for pairwise comparisons (McDonald 2014). To examine changes in diet composition during the breeding season, we compared prey consumed in May with prey from June, also using binomial tests for proportions. We tested the following prey

categories: *A. mellifera*, *Bombus* spp. other bee taxa, Formicidae, other hymenopteran taxa (excluding bees and ants), Coleoptera, and Odonata (Table 1). Statistical analysis was carried out with R v4.3.3, using the stats package (R Core Team 2024).

Results

We collected and analyzed the content of 68 pellets, from which we identified 1236 prey individuals. The number of individuals per pellet ranged from 7 to 78 individuals. In our study, bee-eaters fed almost exclusively on hymenopterans, the remains of which were found in all analyzed pellets, while other insect orders were present in about 53% of the pellets and accounted for only 6.4% of the analyzed prey items (Table 1). The predominant prey was the Honey Bee (identified in 59 pellets, i.e. 86.8%), followed by bumble bees (*Bombus* spp.) in 36 pellets (52.9%) and ants (Formicidae) in 23 pellets (33.8%) (Table 1). In terms of total prey abundance, Honey Bees accounted for 59.0% of all extracted prey individuals, followed by ants with 11.4% and bumble bees with 9.3%. The sum of other bee taxa represented 8.6% of the total prey abundance, other diverse hymenopteran taxa (excluding bees and ants) accounted for 5.3%, coleopterans

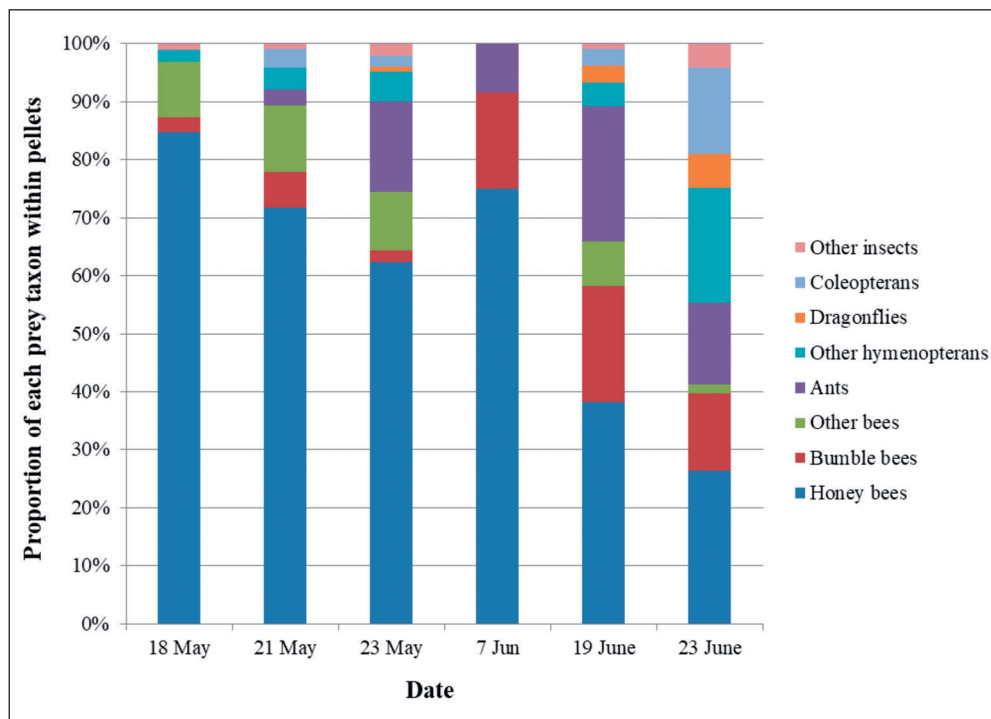


Figure 1. The proportion of various prey categories (less represented taxa shown subsumed) in bee-eaters' pellets by sampling days

1. ábra A különböző zsákmánykategóriák (a kevésbé reprezentált taxonok összeadva) aránya a gyurgyalag köpetekben mintavételi napok szerint

(Coleoptera) for 3.4%, dragonflies (Odonata) for 1.5%, and all other insects constituted 1.5% of the bee-eaters' diet (*Table 1*). The proportion of Honey Bees in the analyzed pellets was significantly higher than that of other prey categories (binomial tests: $p < 0.001$), constituting over 90% of the total prey individuals in some of the analyzed pellets. Similarly, all other hymenopterans were more represented in the bee-eaters' diet than the sum of all non-hymenopteran insects (binomial test: $p < 0.001$). Bee-eaters consumed significantly more Honey Bees and other bee taxa in May than in June, while the opposite was true for all other tested taxa (binomial tests: $p < 0.01$) (*Figure 1*).

Discussion

Hymenopterans are the main prey of adult bee-eaters in many parts of their range (Fuisz *et al.* 2013, Arbeiter *et al.* 2014, Ullmann *et al.* 2017). Among hymenopterans, the Honey Bee was the predominant prey in our study. The proportion of Honey Bees in the bee-eaters' diet varies among regions and seasons, and is typically higher in colonies close to beehives (Costa 1991, Galeotti & Inglisa 2001, Arbeiter *et al.* 2014, Farinós-Celdrán *et al.* 2016). In Sardinia, for example, the proportion of Honey Bees in the bee-eaters' diet ranged from 3.9% to 19.9% in areas without beehives, whereas it was considerably higher, 46.2% to 62.5%, in areas near beehives (Galeotti & Inglisa 2001). Similarly, a study in Portugal found that Honey Bees comprised 50% of the diet of bee-eaters hunting near beehives, but only 10% in those foraging away from beehives (Costa 1991). Although we did not observe any beehives near the study site, the high proportion of Honey Bees in the diet suggests that beehives were likely located in close proximity to the bee-eater colony. Additionally, managed apiaries have previously been reported within a 2 km radius of the bee-eater colony (Bila Dubaić *et al.* 2021). Finally, a remarkable presence of free-living Honey Bees was documented in many parts of Belgrade, with numerous colonies and frequent swarming in some years (Bila Dubaić *et al.* 2021). Accordingly, some Honey Bee colonies were undoubtedly available as an easily accessible food source near the study site. The proportion of consumed Honey Bees decreased as the breeding season progressed (*Figure 1*), indicating a shift toward other prey categories during the chick provisioning period (Inglisa *et al.* 1993, Arbeiter *et al.* 2014), which may be due to phenological changes in activity and the relative availability of different groups.

In addition to Honey Bees, the closely related bumble bees also represented attractive prey for bee-eaters, as their remains were detected in more than half of the examined pellets. However, the share of bumble bees in the total number of identified prey was considerably lower than in some other studies. For example, bumble bees were the most important prey in the north and northwest of Europe, presumably due to the favorable influence of the oceanic climate, while hot summers may pose challenges in more continental areas (Krüger 2018, Bastian & Bastian 2024). In such areas (from central through eastern Europe), bumble bees were recorded as common prey in colonies close to suitable habitats, e.g. clover fields and flowering grasslands (Fry 1984), but also later in the summer (Krištin 1994). Bumble bees are well known for their generalist and highly opportunistic foraging behavior, as well as

for local differences and seasonal variation in population abundance (Goulson *et al.* 2008, Goulson 2010, Pyke *et al.* 2011), which may affect their availability and attractiveness to bee-eaters. Our previous long-term observations in the wider Belgrade area indicate that the abundance and local activity of bumble bees are strongly affected by the availability of more favorable habitats, and the Višnjička Kosa study site does not represent a favorable area in that respect (Četković, unpublished data). The number and relative share of bumble bee prey items were significantly higher in June, likely due to the seasonal growth of their colonies.

In our study, bee-eaters also captured a considerable number of ants. These hymenopterans are also common prey for bee-eaters in Europe, as the timing of the nuptial flight period in the life cycle of many ant species overlaps with the birds' breeding season (Fry 1984, Seifert 2017). For example, ants were identified as the second most frequently consumed prey at a study site in Slovakia, being more prevalent in the diet of nestlings than adults (Goffová *et al.* 2022). We recorded only a few individuals of ants per sample, with the exception of two pellets in which ants were the most abundant prey, suggesting that some bee-eaters succeeded to detect local ant swarming.

Although some research indicates that bee-eaters generally prefer hymenopterans, which may dominate their diet even when not the most abundant flying insects (Fry 1984, Inglis *et al.* 1993), bee-eaters typically capture the most abundant insect species in higher proportions, depending on the season and habitat (Fry 1983, Bastian & Bastian 2024). For example, dragonflies are the dominant prey of bee-eaters whose colonies are located close to aquatic habitats (Fuisz *et al.* 2013, Bastian & Bastian 2024). In addition, a recent study revealed that the proportion of hymenopterans in the diet of bee-eaters is overestimated if the diet is assessed only through analysis of pellets, i.e., without direct observations or photographic surveys of birds; weakly sclerotized insects, such as lepidopterans and dragonflies may be largely digested to unrecognizable remains and thus underrepresented in pellets (Bastian & Bastian 2023). A photographic survey of prey delivered to nests in a colony near wetland habitats revealed a high consumption of dragonflies (Fuisz *et al.* 2013), with their proportion comparable to that of all hymenopterans combined. These soft-bodied insect groups were poorly represented (e.g. dragonflies, dipterans) or completely absent (e.g. lepidopterans) in our study, which may, in part, be due to the methodology we applied.

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