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Ornis Hungarica 2025. 33(2): 272–291.
DOI: 10.2478/orhu-2025-0033

Orthopteran prey sources of Red-footed Falcon *(Falco vespertinus)* on grasslands near their nesting sites in Serbia

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Received: August 30, 2024 – Revised: July 28, 2025 – Accepted: July 30, 2025

Purger, J. J., Kisbenedek, T. & Purger, D. 2025. Orthopteran prey sources of Red-footed Falcon *(Falco vespertinus)* on grasslands near their nesting sites in Serbia. – Ornis Hungarica 33(2): 272–291. DOI: 10.2478/orhu-2025-0033

Abstract Red-footed Falcons *(Falco vespertinus)* in the breeding period feed mainly on orthopteran insects. Theoretically, the availability of this food source may affect the size of the colonies of nesting birds and breeding success. We hypothesized that in the grassland habitats around larger colonies, sources of the orthopteran prey are richer in quality and quantity than around smaller colonies or solitary nests. Furthermore, we predicted that during the growth of the nestlings, the individuals of orthopteran species that are potential prey also grow over time. Orthopteran assemblages living in grasslands near 19 Red-footed Falcon nesting sites were sampled with sweep-nets in the northern province of Serbia, Voivodina, in June and July 2003. A total of 1,454 individuals of 25 Orthoptera species were identified in the study area, 21 species from the samples in Bachka (region between the Danube and Tisa River), while 24 species were collected in the Banat (areas east of the Tisa River). Individuals of larger orthopteran species were found only sporadically. At the same time with growths of Red-footed Falcon nestlings, from June to July, neither the potentially available orthopteran species nor the number of their individuals changed significantly. The body length of the most common orthopteran species Common Straw Grasshopper *(Euchorthippus declivus)* was significantly larger in July than in June. We could not detect relationship between the size of the Red-footed Falcon colonies and the number of species and individuals of the orthopterans. The proper management and conservation of these overgrazed and degraded grasslands should be a priority task, since these are hunting areas for Red-footed Falcons and at the same time, the habitats of several rare and in Serbia protected Orthoptera species e.g. Steppe Spiny Bush-cricket *(Gampsocleis glabra)*, Veysel's Slender Bush-cricket *(Tessellana veyseli)* and Cone-headed Grasshopper *(Acrida ungarica)*.

Keywords: food supply, sweep-netting, Orthoptera, overgrazing, Voivodina

Összefoglalás A kék vércsék *(Falco vespertinus)* a szaporodásuk időszakában főként egyenesszárnyú (Orthoptera) rovarokkal táplálkoznak. Ennek a táplálékforrásnak az elérhetősége elméletben befolyásolhatja a madarak fészkelő telepeinek nagyságát és költési sikerét. Azt feltételeztük, hogy a nagyobb telepek körüli füves élőhelyeken gazdagabb az egyenesszárnyú fajok minőségi és mennyiségi kínálata, mint a kisebb telepek vagy magányos fészkek körül, valamint a fészkekben nevelkedő fiókák növekedésével a táplálékul szolgáló egyenesszárnyú fajok egyedei is idővel nőnek. A kék vércse 19 fészkelőhelye közelében található füves területeken élő egyenesszárnyú-együttesekből fűhálóval vettünk mintát Szerbia északi tartományában, a Vajdaságban, 2003 júniusában és júliusában. A vizsgált területen összesen 25 egyenesszárnyú-fajt (1454 egyed) mutattunk ki: Bácskában (a Duna-Tisza közén) 21 faj, míg Bánátban (a Tiszától keletre eső területeken) 24 egyenesszárnyú-faj egyedeit gyűjtöttük be. A nagyobb testű egyenesszárnyú-fajok egyedei csak elvétve kerültek elő. A kék vércse fiókák növekedésével egyidőben, júniustól júliusig, sem a potenciálisan elérhető egyenesszárnyúak fajszáma, sem azok egyedszáma nem változott jelentősen. Azonos mintavételi helyeken a leggyakoribb egyenesszárnyú-faj a rövidszárnyú rétisáska *(Euchorthippus declivus)* testhossza júliusban azonban szignifikánsan nagyobb volt, mint júniusban. A kék vércse telepek nagysága és az egyenesszárnyúak faj- és egyedszáma között nem tudtunk statisztikailag jelentős összefüggést kimutatni. A vizsgált füves területek többsége túllegeltetett és degradált, de a kék vércsék vadászterületei és egyúttal több Szerbiában ritka és védett Orthoptera fajnak, mint pl. a tőrös szöcské-

nek *(Gampsocleis glabra)*, a sávos rétiszöcskének *(Tessellana veyseli)* és a sisakos sáskának *(Acrida ungarica)* is az élőhelyei, ezért megőrzésük és megfelelő kezelésük prioritást kell, hogy élvezzen.

Kulcsszavak: táplálék kínálat, fűhálózás, Orthoptera, túllegeltetés, Vajdaság

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Introduction

The population of the mainly insectivorous Red-footed Falcon *(Falco vespertinus)*, which breeds in the steppe and forest-steppe areas of the temperate zone of the Palearctic region, is showing a declining trend (Cramp & Simmons 1980, Tomialojc 1994, BirdLife International 2024). The primary reason for this is the lack of suitable nesting sites (Bagyura & Palatitz 2004) and the scarcity of insects that serve as food, which is caused by the destruction of natural steppic habitats and use of pesticides (Snow & Perrins 1998, Ham & Rašajski 2000). The southwestern limit of the distribution of the Red-footed Falcon is in the southeastern part of the Carpathian Basin (Pannonian Plain), in the plains of northern part of Serbia, where from May to the end of July it breeds in pairs or in small or large colonies in abandoned nests of crows (Corvidae), mainly Rooks *(Corvus frugilegus)* (Ham & Rašajski 2000, Purger & Lukács 2022). The breeding success of Red-footed Falcons is significantly influenced by availability of food supply in the vicinity of nesting areas (Fehérvári *et al.* 2011, Krištín *et al.* 2017). Moreover, larger colonies can only be formed near large pastures, where they have enough food to raise their young (Bagyura & Palatitz 2004, Palatitz *et al.* 2011, Fehérvári *et al.* 2012). The food composition of Red-footed Falcon was examined during nesting and migration based on the content of their spits and stomach (e.g. Csiki 1910, Budnithshenko 1950, Keve & Szijj 1957, Fülöp & Szlivka 1988), as well as from food residues collected from nests (e.g. Haraszthy *et al.* 1994, Purger 1998, Szövényi 2015, Tulis *et al.* 2017), and at resting places (e.g. Budnithshenko 1950, Balát & Bauer 1955, Bezzel & Hölzinger 1969, Gjerkeš & Lipej 1992, Alivizatos & Kassinis 2021). The larger prey carried by the bird parents can also be determined based on camera recordings (e.g. Horváth 1955, 1964, Chavko & Krištín 2017, Tulis *et al.* 2017). During the nesting period, they feed mainly on orthopterans (Szövényi 2015), but they often carry small vertebrates to the nestlings (e.g. Horváth 1955, 1964, Fülöp & Szlivka 1988, Purger 1998). These studies showed the share of prey species in the food of adult birds and nestlings (Szövényi 2015), but what is less known is where and under what conditions Red-footed Falcons catch their prey (Palatitz *et al.* 2015). During the growing of nestlings, they primarily hunt on grasslands near the breeding site and most of the prey is caught on the ground or nearby (Haraszthy *et al.* 1994). The management of pastures greatly affects the composition and populations of the orthopterans (e.g. Batáry *et al.* 2007, Qin *et al.* 2017, Gardiner 2018). Gustin and Ferrarini (2021) found that almost 40% of hovering and perching activity of adult Red-footed Falcons occurred within a 50 m radius around the nests. In addition to grasslands, they also regularly

visit agricultural fields, and in years with a shortage of food, they even hunt at several kilometers distance (Palatitz *et al.* 2015). With the growth of the nestlings especially in the second part of the fledging period, large bodied and later smaller Orthoptera appear in the food (Horváth 1955, 1964). Little is known about the food resources near nesting sites (Szövényi 2015, Krištín *et al.* 2017) and even less of its relationship with the formation of colonies (Haraszthy *et al.* 1994), but this knowledge is essential for the conservation and survival of the Red-footed Falcon.

Our aim was to reveal, based on sampling in the orthopteran communities living in the grasslands near the nesting sites of Red-footed Falcon: 1) the richness of the othopteran species assemblages, the abundance of certain species, and the presence of rare or protected species; 2) the relationship between the size of the colonies and the richness of the prey; 3) the temporal change of the food supply and the average body size of the potential orthopteran prey items during the breeding season progresses.

Materials and Methods

Study area

The study was performed in the southern part of Central Europe, in the northern part of Serbia, in Voivodina province (approximately 21,500 km^2) which is divided by the Danube and the Tisa rivers into three regions: Bachka (Bačka) in the northwest, Banat in the east and Srem in the southwest (Bezdan *et al.* 2024). The area of Voivodina is mostly flat, and more than 60% is covered by loess and loess-like sediments (Gavrilov *et al.* 2015), on which fertile chernozem soil has formed, and therefore, approx. 75% of its area is arable land with very intensive agricultural production (Galic *et al.* 2019). However, in the area with seminatural and natural habitats sub-pannonic and pannonic steppe grasslands are distributed. In the southern part of the Carpathian Basin, there are also saline soils, on which pannonic salt steppes and salt marshes can be found (Bagi *et al.* 2011). In total, the grasslands cover about 1,500 km^2, and two-thirds of them are used as pasture. About 80% of these grasslands are east of the Tisa River in Banat (Erić *et al.* 2003). Due to their low productivity, saline soils are less affected by agricultural production, thus preserving many relict components of the natural landscape (Zeremski *et al.* 2021). Even so, only 6.4% (1,380 km^2) of the area of Voivodina is protected (Puzović *et al.* 2015). The known nesting sites of Red-footed Falcons (less of which is located in Bachka, but most of them in Banat) overlap with the distribution of saline soils and steppic grasslands (Ham & Rašajski 2000, Purger 2008, Barna 2015, Purger & Lukács 2022).

The climate of Voivodina is moderate continental with cold winters and hot and humid summers, and with a huge range of extreme temperatures featuring inconsistent amounts of rainfall over the course of months (Gavrilov *et al.* 2015). In the period between 1949 and 2006, the mean annual air temperature was 11.1 °C and annual amount of precipitation was 606 mm (Tošić *et al.* 2014).

Sampling methods

The sampling of insects was carried out in the summer of 2003 in the grasslands near the nesting sites of Red-footed Falcons *(Figure 1)*, in the places where we observed the adult birds hunting. Vegetation was low in most of the sampling sites due to intensive grazing *(Figure 2)*. In all locations, sweep-net sampling was conducted between 10 and 16 hours on windless sunny days. A transect consisted of 25 sweeps taken on 25 consecutive strides using a 40-cm diameter sweep-net with a white canvas net bag (e.g. O'Neill *et al.* 2002).

We took 13 samples near 12 nesting sites in 2003 in the period June 20–24. Of these, 6 samples (*Table 1*, samples: 1, 10, 14, 25, 31, 37) are from the vicinity of solitary breeding pairs (or small colonies of 2–5 pairs), while another 6 samples (*Table 1*, samples: 4, 18, 21, 28, 33, 39) were taken near larger colonies (7–24 pairs nested). Based on these samples, in the first step, we checked the normal distribution of the data series using the Shapiro–Wilk test for the number of breeding pairs (colony size), the number of species and individuals of detected orthopterans. In the case of all three parameters, the test confirmed the normal distribution, so

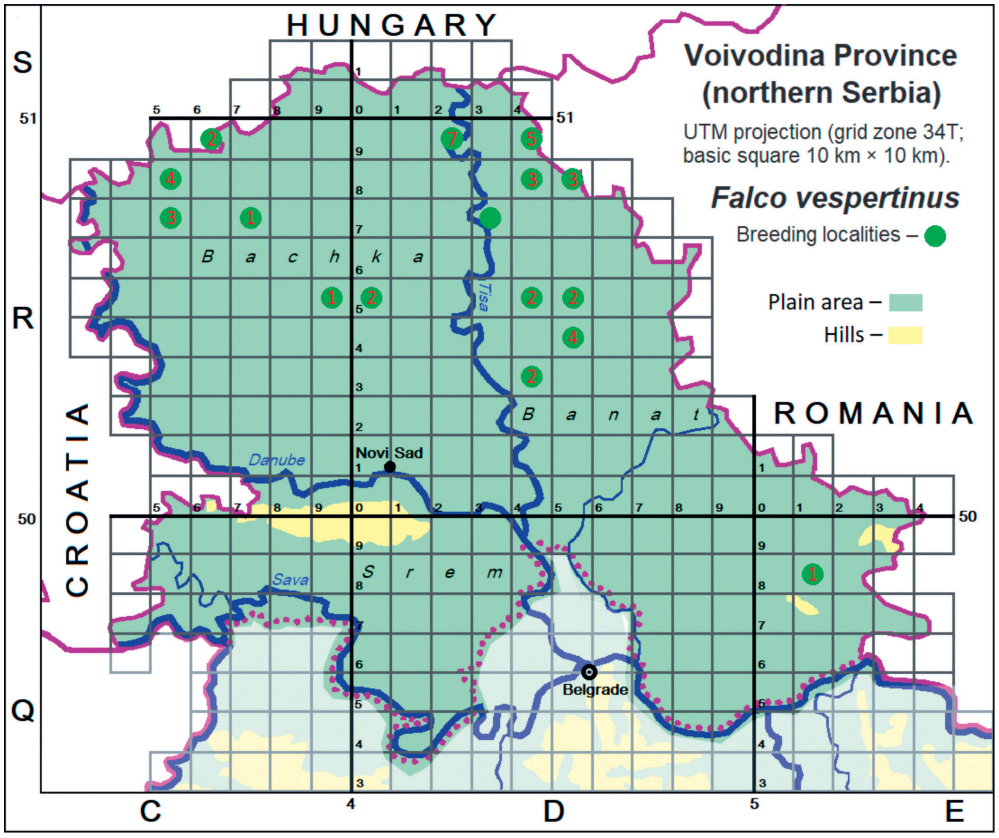

Figure 1. Red-footed Falcon breeding localities in Voivodina in 2003 (green circles), with numbers of sweep-net samplings

1. ábra A kék vércsék fészkelőterületei Vajdaságban 2003-ban (zöld körök) a fűhálózások mintavételi számával

Figure 2. Most of the pastures were overgrazed and degraded, so the number of species and individuals of orthopteran insects were smaller than expected. Red-footed Falcons breeded in the Rook nests on the black-locust trees, Mokrin (Vašarište), 10 July 2003 (Photo by J. J. Purger)

2. ábra A legelők többsége a túllegeltetés miatt degradált volt, így az egyenesszárnyúak faj- és egyedszáma kisebb volt mint várható. Az akácokon lévő vetési varjú fészkekben költöttek a kék vércsék. Mokrin (Vašarište), 2003. július 10. (Fotó: Purger J. J.)

a two-sample t-test was used to test the assumed differences in the distribution of the number of Red-footed Falcon breeding pairs and the number of species and individuals of orthopterans (Hammer *et al.* 2001, Zar 2010). We also took an additional sample at Zimonjić site from the narrow strip of saline meadow along the channel crossing the pasture, from which we saw Red-footed Falcon hunting several times (*Table 1*, sample 15).

Sampling was carried out in the same year at 29 locations near 18 nesting sites, between 7 and 11 of July. In most places we took two samples in July, as there were more Red-footed Falcons hunting, and since the low numbers of catches in June, we considered additional sampling to be justified *(Table 1)*. The collected material was placed in a plastic freezer bag filled with 70% ethanol with zip closure and transported to the laboratory. The material was determined to species level by using identification keys (Harz 1969, 1975, Harz & Kaltenbach 1976). After the determination, we measured the body length of each orthopteran individual.

We compared the body lengths of the two most common species Common Straw Grasshopper *(Euchorthippus declivus)* and Meadow Grasshopper *(Pseudochorthippus*

Table 1. Breeding sites and number of breeding pairs (BP) of Red-footed Falcon in Voivodina in 2003, with the date and location of sweep-netting and the number of collected orthopteran species (Sp) and specimens (N)

1. táblázat A kék vércse költőhelyei és a költő párok száma (BP) Vajdaságban 2003-ban, a fűhálózások dátumával és helyével, a befogott egyenesszárnyúak fajszámával (Sp) és egyedszámával (N)

UTM	Locality/Sample, Date	Latitude °N	Longitude °E	Alt.	BP	Sp	N
CR57	Obzir	45.8387	19.1669	85	3		
	1. 21.06.2003.	45.8387	19.1672	85		3	27
	2. 07.07.2003.	45.8385	19.1671	86		3	17
	3. 07.07.2003.	45.8389	19.1671	85		2	13
CR58	S-W part of Stanišić	45.9275	19.1567	88	7		
	4. 20.06.2003.	45.9278	19.1556	87		3	11
	5. 07.07.2003.	45.9281	19.1562	88		4	14
	6. 07.07.2003	45.9295	19.1553	86		3	7
CR58	N-E part of Stanišić	45.9458	19.1746	94	3		
	7. 07.07.2003.	45.9450	19.1732	94		5	27
CR69	3km N-E of Stanišić	45.9484	19.2314	100	1		
	8. 07.07.2003.	45.9489	19.2309	100		2	17
	9. 07.07.2003.	45.9476	19.2310	99		5	6
CR77	2.5 km W of Gornja Rogatica	45.7937	19.4327	110	5		
	10. 20.06.2003.	45.7945	19.4330	109		3	4
CR95	3 km S of Feketić	45.6361	19.6996	90	2		
	11. 07.07.2003.	45.6363	19.7019	90		2	20
DR05	4 km E of Feketić	45.6876	19.7623	94	7		
	12. 07.07.2003.	45.6869	19.7621	94		7	35
	13. 07.07.2003.	45.6865	19.7615	94		6	32
DR29	2.5 km N-W of Zimonjić	46.0495	19.9594	83	2		
	14. 20.06.2003.	46.0499	19.9609	79		5	44
	15. 20.06.2003. *Juncus*	46.0490	19.9614	79		10	347
	16. 11.07.2003.	46.0505	19.9601	80		3	19
	17. 11.07.2003. *Juncus*	46.0491	19.9615	79		9	83
DR29	3 km S-W of Mali Pesak	46.0556	19.9624	81	24		
	18. 21.06.2003.	46.0572	19.9658	79		5	25
	19. 11.07.2003.	46.0548	19.9609	80		4	6
	20. 11.07.2003.	46.0535	19.9581	80		8	47
DR37	2 km N-W of Padej	45.8406	20.1384	74	1		
DR43	Okanj, 3 km S-W of Melenci	45.4911	20.2965	77	10		
	21. 23.06.2003.	45.4906	20.2970	75		4	34
	22. 10.07.2003.	45.4906	20.2940	75		7	38
DR45	10 km E of Novi Bečej	45.6247	20.2634	75	13		

UTM	Locality/Sample, Date	Latitude °N	Longitude °E	Alt.	BP	Sp	N
	23. 10.07.2003.	45.6251	20.2641	75		9	34
	24. 10.07.2003.	45.6242	20.2641	75		11	62
DR48	2 km S-E of Jazovo	45.8894	20.2427	75	3		
	25. 23.06.2003.	45.8891	20.2423	76		3	40
	26. 11.07.2003.	45.8894	20.2418	75		6	49
	27. 11.07.2003.	45.8883	20.2423	75		5	76
DR48	Jazovo (N part)	45.9038	20.2243	75	1		
DR49	2 km S-W of Vrbica	45.9973	20.2944	73	12		
	28. 23.06.2003.	45.9971	20.2943	73		4	27
	29. 10.07.2003.	45.9969	20.2942	73		4	18
	30. 10.07.2003.	45.9975	20.2935	73		5	23
DR49	1 km E of Banatski Monoštor	45.9631	20.2909	73	1		
	31. 21.06.2003.	45.9638	20.2904	73		2	3
	32. 10.07.2003.	45.9625	20.2895	74		6	12
DR54	Torda (S-E part)	45.5797	20.4677	73	13		
	33. 10.06.2003.	45.5795	20.4679	73		3	18
	34. 10.07.2003.	45.5794	20.4678	73		4	17
	35. 10.07.2003.	45.5793	20.4675	73		2	22
DR54	2 km S of Torda	45.5672	20.4648	72	1		
	36. 10.07.10.	45.5660	20.4667	72		6	56
DR55	1 km S-E of Bašaid	45.6365	20.4236	79	2		
	37. 23.06.2003.	45.6367	20.4216	78		3	5
	38. 10.07.2003.	45.6379	20.4226	78		8	35
DR58	Mokrin (Vašarište)	45.9421	20.3954	72	15		
	39. 21.06.2003.	45.9416	20.3955	73		1	3
	40. 10.07.2003.	45.9424	20.3939	70		4	52
	41. 10.07.2003.	45.9415	20.3963	73		6	24
EQ18	Potporanj	45.0301	21.2399	86	2		
	42. 12.07.2003.	45.0307	21.2398	86		3	5
	Total number of nesting Red-footed Falcon pairs in 2003:				**128**		
	Number of collected orthopteran species and specimens:					**25**	**1454**

parallelus) from June (*Table 1*, samples: 1, 4, 14, 18, 21, 25, 28, 31, 33, 37, 39) and July (*Table 1*, samples: 2, 5, 16, 19, 22, 26, 29, 32, 34, 38, 41) samples from the same 11 sampling locations. Since the two species were present in different numbers in the June and July samples, we randomly selected the same number of individuals for comparison. In the next step, we performed a normality test, and since the measured body length did not fit the normal distribution for any of the species, we used a non-parametric Wilcoxon paired-rank test to test for differences in the measured parameters (Hammer *et al.* 2001, Zar 2010).

Table 2. Threat category of the orthopteran species in Europe (and in Serbia) according to IUCN criteria (End. – Endemic, * – strictly protected in Serbia), and number of collected specimens in region Bachka and Banat

2. táblázat Az egyenesszárnyú fajok veszélyezettségi kategóriája Európában (és Szerbiában) az IUCN kritériumai szerint (End – endemikus, * – Szerbiában fokozottan védett) és a begyűjtött példányok Bácskában és Bánátban

Species	Status	Bachka	Banat	Total
Ensifera				
Conocephalus fuscus (Fabricius, 1793)	LC	12	2	14
Ruspolia nitidula (Scopoli, 1786)	LC	4	5	9
Leptophyes albovittata (Kollar, 1833)	LC	7	19	26
Gampsocleis glabra (Herbst, 1786)	NT (VU) *		1	1
Bicolorana bicolor (Philippi, 1830)	LC	4	4	8
Roeseliana roeselii (Hagenbach, 1822)	LC	1	1	2
Platycleis grisea (Fabricius, 1781)	LC	4	5	9
Tessellana veyseli (Kocak, 1984)	LC (NT) *	5	12	17
Oecanthus pellucens (Scopoli, 1763)	LC	0	3	3
Caelifera				
Acrida ungarica (Herbst, 1786)	LC (End.) *	1	5	6
Calliptamus italicus (Linnaeus, 1758)	LC	18	5	23
Pezotettix giornae (Rossi, 1794)	LC	15		15
Chorthippus oschei Helversen, 1986	LC	25	4	29
Chorthippus biguttulus (Linnaeus, 1758)	LC	1	9	10
Chorthippus brunneus (Thunberg, 1815)	LC	7	18	25
Chorthippus dichrous (Eversmann, 1859)	LC	20	2	22
Chorthippus dorsatus (Zetterstedt, 1821)	LC	32	8	40
Pseudochorthippus parallelus (Zetterstedt, 1821)	LC	78	71	149
Dociostaurus brevicollis (Eversmann, 1848)	LC		1	1
Dociostaurus maroccanus (Thunberg, 1815)	LC	1	5	6
Euchorthippus declivus (Brisout de Barneville, 1848)	LC (End.)	549	442	991
Omocestus haemorrhoidalis (Charpentier, 1825)	LC	2	3	5
Omocestus rufipes (Zetterstedt, 1821)	LC	1	2	3
Stenobothrus crassipes (Ocskay in Charpentier, 1825)	LC (End.)		6	6
Aiolopus thalassinus (Fabricius, 1781)	LC	14	20	34
Total number of individuals		**801**	**653**	**1454**
Number of species		**21**	**24**	**25**

Results

A total of 42 samples were taken from the Orthoptera assemblages of the grassland areas near the 19 nesting sites of the Red-footed Falcon *(Figure 1, Table 1)*. The average number of species detected in each sample was 4.7 (SD=2.36), and the average number of individuals was 34.6 (SD=53.03). We caught a total of 1,454 individuals of 25 orthopteran species *(Table 2)*. Most of the species are considered common but there were three species endemic to Europe, the Cone-headed Grasshopper *(Acrida ungarica)*, the Common Straw Grasshopper *(Euchorthippus declivus)* and the Pygmy Toothed Grasshopper *(Stenobothrus crassipes)* (Hochkirch *et al.* 2016). We detected in the samples three species in the samples, which are strictly protected in Serbia *(Table 2)*. A single specimen of the Steppe Spiny Bush-cricket *(Gampsocleis glabra)* was collected in the pasture in Mokrin *(Figure 2, Table 3d)*; individuals of Veysel's Slender Bush-cricket *(Tessellana veyseli)* were found in ten samples *(Table 3b, c, d)*; the only large-bodied species (with body length exceeding 30 mm) was the Cone-headed Grasshopper from which we collected 6 specimens from four samples in the vicinity of Stanišić, Novi Bečej and Jazovo *(Table 3a, c)*.

The number of species (3 species) and the number of individuals (20 individuals) of Orthoptera in the vicinity of breeding sites of solitary Red-footed Falcons (or 1–5 pairs) were likely to be those in grassland habitats near larger colonies (7–24 pairs) *(Table 4)*.

In Bachka, 801 individuals of 21 Orthoptera species were found in 20 samples *(Figure 1, Table 3a)* and one species, Common Maquis Grasshopper *(Pezotettix giornae)* was collected only in Bachka. In Banat, we collected 653 individuals of 24 species from 22 samples *(Table 3c, d)* and we detected individuals of four species: Steppe Spiny Bush-cricket, Tree-cricket *(Oecanthus pellucens)*, Intermediate Cross-backed Grasshopper *(Dociostaurus brevicollis)* and Pygmy Toothed Grasshopper that were found only in Banat.

Table 3a Number of orthopteran species and specimens collected at sampling sites (1–10)
3a táblázat A mintavételi helyeken (1–10) gyűjtött egyenesszárnyúak faj- és egyedszáma

Species ↓ Samples →	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
Conocephalus fuscus		1			1		4			
Ruspolia nitidula			1							
Leptophyes albovittata										2
Bicolorana bicolor	1			1					1	1
Acrida ungarica									1	
Calliptamus italicus					1	1	1			
Chorthippus brunneus							2			
Chorthippus dichrous									1	
Pseudochorthippus parallelus	1	9		3	4	2	4	6	2	
Euchorthippus declivus	25	7	12	7	8	4	16	11	1	
Aiolopus thalassinus										1
Number of species	**3**	**3**	**2**	**3**	**4**	**3**	**5**	**2**	**5**	**3**
Number of specimens	**27**	**17**	**13**	**11**	**14**	**7**	**27**	**17**	**6**	**4**

Table 3b Number of orthopteran species and specimens collected at sampling sites (11–20)
3b táblázat A mintavételi helyeken (11–20) gyűjtött egyenesszárnyúak faj- és egyedszáma

Species ↓ Samples →	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
Conocephalus fuscus							6			
Ruspolia nitidula		3								
Leptophyes albovittata		3	1					1		
Roeseliana roeselii					1					
Platycleis grisea					4					
Tessellana veyseli		1	1		2		1			
Calliptamus italicus		10	1		2		2			
Pezotettix giornae							11	4		
Chorthippus oschei				2	9	1	7			6
Chorthippus biguttulus										1
Chorthippus brunneus		2	3							
Chorthippus dichrous				5	9		1			4
Chorthippus dorsatus					2	8	12		1	9
Pseudochorthippus parallelus	1	8	16	6	12		1	1	1	1
Dociostaurus maroccanus				1						
Euchorthippus declivus	19	8	10	30	300	10	42	18	3	18
Omocestus haemorrhoidalis									1	1
Omocestus rufipes								1		
Aiolopus thalassinus					6					7
Number of species	**2**	**7**	**6**	**5**	**10**	**3**	**9**	**5**	**4**	**7**
Number of specimens	**20**	**35**	**32**	**44**	**347**	**19**	**83**	**25**	**6**	**47**

In June, we detected individuals of 19 species from the 13 samples, among them the Moroccan locust *(Dociostaurus maroccanus)*, which was absent from the samples collected in July *(Table 2, 3a, b, c, d)*. In July, we detected the presence of 24 species out of 29 samples and individuals of six species: Long-winged Conehead *(Conocephalus fuscus)*, Large Conehead *(Ruspolia nitidula)*, Steppe Spiny Bush-cricket, Tree-cricket, Intermediate Cross-backed Grasshopper and Orange-tipped Grasshopper *(Omocestus haemorrhoidalis)* were collected only in this month *(Table 2)*. We could not detect any significant differences ($\chi^2 = 0.296$, df = 1, P = 0.586) in the numbers of orthopterans in samples collected in June and July (237 individuals of 15 species vs. 249 individuals of 17 species) near the 11 Red-footed Falcon breeding sites *(Table 5)*.

The average body length (16.91 mm) of the most common Common Straw Grasshopper individuals (n = 142) collected in July was significantly greater (Wilcoxon test, z = 3.51, P = 0.0001) than that of the individuals (n = 142) collected in June (15.70 mm) *(Figure 3)*. The body length of the second most common species, Meadow Grasshopper, did not show any significant differences when comparing samples collected in June (17.76 mm, n = 29) and July (16.90 mm, n = 29) (Wilcoxon test, z = 1.43 P = 0.15).

Table 3c Number of orthopteran species and specimens collected at sampling sites (21–31)
3c táblázat A mintavételi helyeken (21–31) gyűjtött egyenesszárnyúak faj- és egyedszáma

Species ↓ Samples →	**21.**	**22.**	**23.**	**24.**	**25.**	**26.**	**27.**	**28.**	**29.**	**30.**	**31.**
Conocephalus fuscus				1							
Ruspolia nitidula			1						3		
Leptophyes albovittata			1				1	2	1	6	
Bicolorana bicolor			1								
Platycleis grisea			2	1						2	
Tessellana veyseli		3	1								
Oecanthus pellucens						1					
Acrida ungarica			1	3	1						
Calliptamus italicus		1						1		2	
Chorthippus oschei		3		1							
Chorthippus biguttulus	1	7					1				
Chorthippus brunneus	1	5		1		1	2				1
Chorthippus dorsatus		5		2							
Pseudochorthippus parallelus			1		1	2	2	11	11	12	
Dociostaurus brevicollis				1							
Dociostaurus maroccanus	5										
Euchorthippus declivus	27	14	25	43	38	43	70	13	3	1	2
Omocestus haemorrhoidalis				2							
Omocestus rufipes						1					
Stenobothrus crassipes			1	1							
Aiolopus thalassinus				6		1					
Number of species	**4**	**7**	**9**	**11**	**3**	**6**	**5**	**4**	**4**	**5**	**2**
Number of specimens	**34**	**38**	**34**	**62**	**40**	**49**	**76**	**27**	**18**	**23**	**3**

Discussion

We confirmed the presence of individuals of 25 orthopteran species in grasslands near nesting sites of Red-footed Falcons in the lowland areas of Voivodina, which is 22.5% of the 111 species occurring in this north Serbian province (Ivković 2014–2024). Most of the species that we detected are common, but there were also rare and endangered species e.g. the xerothermic habitat specialist Steppe Spiny Bush-cricket (Grzędzicka & Vahed 2020), which in Serbia is Vulnerable (VU) and Veysel's Slender Bush-cricket, which is Near Threatened (NT) (Pavićević *et al.* 2018).

During a similar study in the Vásárhelyi Plain in Hungary using sweep-net sampling and soil traps, 26 species were detected (Szövényi 2015). In Slovakia, individuals of 46 orthopteran species were collected on several sites during the Red-footed Falcon breeding season (Krištín

Table 3d Number of orthopteran species and specimens collected at sampling sites (32–42)
3d táblázat A mintavételi helyeken (32–42) gyűjtött egyenesszárnyúak faj- és egyedszáma

Species ↓ Samples →	**32.**	**33.**	**34.**	**35.**	**36.**	**37.**	**38.**	**39.**	**40.**	**41.**	**42.**
Conocephalus fuscus					1						
Ruspolia nitidula			1								
Leptophyes albovittata					5	1	2				
Gampsocleis glabra									1		
Bicolorana bicolor		3									
Roeseliana roeselii					1						
Tessell ana veyseli	1						2		4	1	
Oecanthus pellucens	1									1	
Calliptamus italicus			1								
Chorthippus brunneus	1						4			1	1
Chorthippus dichrous	2										
Chorthippus dorsatus							1				
Pseudochorthippus parallelus	1	5	1	8	10	1	1		2		2
Euchorthippus declivus	6	10	14	14	38		15		45	19	2
Omocestus haemorrhoidalis							1				
Omocestus rufipes										1	
Stenobothrus crassipes								3		1	
Aiolopus thalassinus					1	3	9				
Number of species	**6**	**3**	**4**	**2**	**6**	**3**	**8**	**1**	**4**	**6**	**3**
Number of specimens	**12**	**18**	**17**	**22**	**56**	**5**	**35**	**3**	**52**	**24**	**5**

Table 4. Comparison of the average species and number of individuals (SD – standard deviation and SEM – standard error of the mean) of orthopterans caught in June in the grassland habitats near the smaller and larger colonies of Red-footed Falcons
4. táblázat A kisebb és nagyobb kék vércse telepek közelében lévő füves élőhelyeken júniusban fogott egyenesszárnyúak átlagos faj- és egyedszámának (±SD – standard deviation and SEM – standard error of the mean) összehasonlítása

Mean of:	**colony size**	**number of species**	**number of individuals**
1–5 pair	2.67 (SD=1.37, SEM=0.56)	3.17 (SD=0.98, SEM=0.40)	20.50 (SD=18.94, SEM=7.73)
7–24 pair	13.50 (SD=5.82, SEM=2.38)	3.33 (SD=1.37, SEM=0.56)	19.67 (SD=11.34, SEM=4.63)
t-test	4.4371	0.2425	0.0925
df	5	5	5
P-value	0.0013	0.8133	0.9282

Table 5. Number of individuals and average body length±SD (mm) of orthopteran species collected at the same 11 Red-footed Falcon nesting sites during sweep-netting sampling in June and July of 2003

5. táblázat A júniusi és júliusi fűhálózások során ugyanazon a 11 kék vércse költőhelynél gyűjtött orthoptera fajok egyedszáma és átlagos testhossza±SD (mm)

Species	June	Mean±SD	July	Mean±SD
Conocephalus fuscus			2	10.00±0.00
Ruspolia nitidula			4	20.75±2.50
Leptophyes albovittata	4	12.75±4.27	3	15.00±0.00
Bicolorana bicolor	5	15.40±3.65		
Tessellana veyseli			7	16.28±0.49
Oecanthus pellucens			3	13.00±2.65
Acrida ungarica	1	18.00±0.00		
Calliptamus italicus	1	17.00±0.00	3	14.00±4.00
Pezotettix giornae	4	16.75±2.50		
Chorthippus oschei	2	15.00±0.00	4	15.00±1.63
Chorthippus biguttulus	1	20.00±0.00	7	16.57±1.13
Chorthippus brunneus	2	17.50±3.54	12	18.00±2.77
Chorthippus dichrous	5	14.80±0.84	2	19.00±4.24
Chorthippus dorsatus			15	15.87±1.96
Pseudochorthippus parallelus	29	17.76±3.01	30	16.87±2.01
Dociostaurus maroccanus	6	18.00±3.10		
Euchorthippus declivus	170	15.56±3.05	142	16.91±2.37
Omocestus haemorrhoidalis			2	15.50±2.12
Omocestus rufipes	1	14.00±0.00	2	14.50±2.12
Stenobothrus crassipes	3	15.67±1.53	1	12.00±0.00
Aiolopus thalassinus	3	14.67±1.15	10	17.20±4.08
Number of individuals	**237**		**249**	
Number of species	**15**		**17**	

et al. 2017). More than half of the species detected in both the Hungarian and Slovakian samples were proven to be on the prey list of Red-footed Falcon (Szövényi 2015, Krištín *et al.* 2017). In our study, the number of individuals of the Orthoptera collected was much smaller (1,454 specimens) than in the samples collected both in Hungary (3,504 specimens) and Slovakia (ap. 14,500 specimens). This can be explained by the fact that our study lasted one year, while sampling was more intensive in Hungary and Slovakia lasted two and three years, respectively (Szövényi 2015, Krištín *et al.* 2017). In addition, in most of our sampling locations, the vegetation was very low due to the overgrazing. Our sampling could have been more effective if the sweep-neting method had been combined, for example, with vacuum sampling, which can more effectively collect smaller invertebrates (e.g. < 5 cm), but this method was not widely used at the time of our survey (Doxon *et al.* 2011). Our samples did

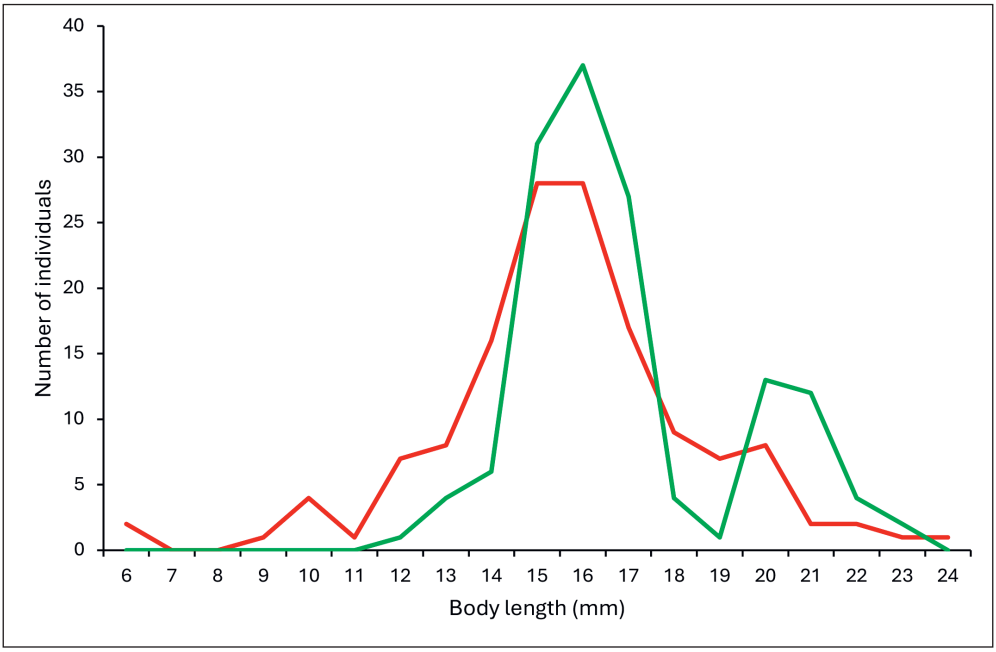

Figure 3. Changes in the body length of the Common Straw Grasshopper *(Euchorthippus declivus)* individuals collected in June (red line) and July (green line)

3. ábra A júniusban (piros vonal) és júliusban (zöld vonal) begyűjtött rövidszárnyú rétisáska *(Euchorthippus declivus)* egyedek testhosszának változása

not contain the Wart-biter *(Decticus verrucivorus)* or the Great Green Bushcricket *(Tettigonia viridissima)* which are the typical large-bodied orthopteran prey of the Red-footed Falcon (Szövényi 2015, Krištín *et al.* 2017, Tulis *et al.* 2017). The sampling method and intensity of grazing have a demonstrable effect on the pasture and on the straggler, communities living there (e.g. Báldi & Kisbenedek 1997, Batáry *et al.* 2007, Báldi *et al.* 2013, Török *et al.* 2016, Gardiner 2018, Almásy *et al.* 2021, Milić *et al.* 2024). With the disappearance of the species typical of tall grasslands, the diversity of orthopteran often decreases (Qin *et al.* 2017, Gardiner 2022, Stefanidis *et al.* 2024). A significant positive correlation between the species richness of Orthoptera and vascular plants was also shown (Essl & Dirnböck 2012).

In the study area, we could not demonstrate a correlation between the size of the Red-footed Falcon colonies and the abundance of orthopteran insects as the potential food resources in the grassland patches near the nesting sites. The low number of orthopterans in our samples primarily reflects the overgrazing of the grasslands, which can be supported by the fact that we found them in significant numbers in non-grazed patches (e.g. in a saline meadow dominated by *Juncus* sp.). Grasslands maintained with moderate grazing are important hunting areas and sources of food for Red-footed Falcon (Fehérvári *et al.* 2009, Palatitz *et al.* 2011, 2015), but overgrazing can result in impoverishment of grassland habitats. Some agricultural crops (e.g. alfalfa or grain fields) may have richer assemblages of Orthoptera than overgrazed grasslands in the Pannonian lowlands (e.g. Arnóczkyné Jakab & Nagy 2021, 2022). Red-footed Falcon is an opportunistic raptor, making use of local abundances and seasonal variations in prey,

with orthopterans as its most abundant food (Cramp & Simmons 1980, Szövényi 2015). In the year of our study, there were no large colonies of 40–50 pairs of Red-footed Falcons in Voivodina (Purger 2008). Keve and Szijj (1957) uncorrectly reported information from the reference in Serbian language (Marčetić & Medaković 1954) that in 1950, there was a colony of 100–200 pairs in Bachka in Voivodina near Bačko Gradište. However, in the cited publication (Marčetić & Medaković 1954) it is stated that „in 1950, 3 pairs nested in a 100–200 m wide black-locust forest at Biserno Ostrvo next to the dead Tisa". The conditions for the formation of large colonies were only present in a few places, but in 1990, 147 pairs nested on the banks of the Tisa tributary Zlatica near Jazovo (Purger 1996). Unfortunately, due to illegal logging and disturbance, in later years there were much fewer pairs breeding in this colony (Purger 2008, Purger & Lukács 2022). Around the settlement, there is vast grassland, a significant part of which is now under the protection of the Special Nature Reserve "Pasture of the Great Bustard – Pašnjaci velike droplje", Important Bird Area (Serbia) (Zeremski *et al.* 2021), and the corresponding due to the management, there are still a significant number of Red-footed Falcons nesting in the area (Barna 2015, Purger & Lukács 2022). The formation of larger colonies is primarily related to the number of available rook nests (e.g. Végvári *et al.* 2002, Barna 2015). However, if the number of nests is not a limiting factor and large colonies are not formed, we presume that it can be explained more by the lack of birds, the lack of adequate food supply and the complex effect of background factors. Near those nesting sites, where grassland habitats are not protected and intensive grazing continues, low-intensity extensive farming should be returned as soon as possible. Improving the condition of grasslands not only helps the naturalness of the habitats, but also the conservation of endangered animal species living there (Baldock 1999, Grdović *et al.* 2012). The condition of grasslands is also important for maintaining populations of common insect (e.g. orthopteran species), amphibian (e.g. Common Spadefoot *Pelobates fuscus*), reptile (e.g. Sand Lizard *Lacert agilis*) and small mammal (e.g. Common Vole *Microtus arvalis*) species, several of which are potential prey for Red-footed Falcons (e.g. Fülöp & Szlivka 1988, Haraszthy *et al.* 1994, Krištín *et al.* 2017). The diversity of orthopterans depended on habitat quality rather than the size of area and connection with similar habitats (Löffler *et al.* 2020). To preserve diversity, it is essential to maintain large patches with traditional land use practices (i.e. rough grazing or mowing once a year) and to restore former habitats to promote species dispersal across fragmented landscapes (Löffler *et al.* 2020). Even less natural grasslands that remain stable elements over long time in an agricultural landscape have extremely important role in conserving orthopterans and other grassland-dwelling insects (Purger & Vadkerti 2004, Riggi & Berggren 2020).

We could not find significant difference in the number of potentially available orthopteran species and individuals in June and July in the studied grassland patches near the Red-footed Falcon nesting sites. As time progressed, the average body length of the individuals of dominant orthopteran species, the Common Straw Grasshopper, increased by more than one millimeter. The Red-footed Falcons needed more food to raise their chicks, while the availability of orthoptera resources in grassland patches was limited. This could probably be the reason for the well-known phenomenon that hunting shifts from natural habitats to agricultural and even arable habitats during the late fledgeling period (Palatitz *et al.* 2011).

To meet the increased food needs of the chicks, the hunting of Common Voles on agricultural areas is more profitable than hunting small orthopterans on grasslands. In the entire sample that we collected, the average body length of the individuals exceeded 16 mm. Despite the lack of large-bodied orthopteran species, Red-footed Falcons could find it worthwhile to hunt individuals of small species if the grassland is close to the nesting site. In the study performed in Hungary, the body length of the insects preyed upon by Red-footed Falcons, breeding in Hortobágy, was only 5–10 mm, and during nestling, one locust was preyed on average every 30 seconds (Haraszthy *et al.* 1994). In the southwestern part of Slovakia, the feeding of 14–26-day-old chicks was studied using cameras and 97% of the prey were insects, more than half of which was Italian Locust *(Calliptamus italicus)*, the frequency of feeding of the chicks was also high, 9.9 feedings per hour (Chavko & Krištín 2017).

Orthoptera, in addition to being an important source of food for Red-footed Falcons, are also good indicators of disturbance and naturalness (Báldi & Kisbenedek 1997). Their monitoring is also important because small habitat island systems include a large proportion of the regional orthopteran species pool in arable landscapes (Riggi & Berggren 2020). Often smaller and more disturbed habitats are unable to support resident insectivore populations, this bottom-up mechanism may underlie the disproportionate sensitivity of insectivores to land-use intensification (Razeng & Watson 2015)

Conclusion

Based on our results, the small number of individuals of orthopteran insects reflects the disturbed, overgrazed state of the grassland patches near breeding sites of the Red-footed Falcons. It may indicate that this food source was not enough for the breeding period and therefore they needed additional food sources. Because of that, we could not show a correlation between orthopteran insects as the food source with the size of the Red-footed Falcon colonies. Due to the presence of rare and protected species detected during the survey, it would be important to place additional grassland areas under protection as soon as possible and to take measures that would regulate the intensity of grazing in such a way that the diversity of the orthopteran species pool and a rich source of food for the Red-footed Falcons are both preserved. A long time has passed since our survey, most of the Red-footed Falcon breeding sites as well as the landscape use changed considerably, therefore it would be worthwile to make similar research in the future.

Acknowledgements

We would like to thank Zsolt Lukács and late Sándor Lukács† for their help in field work, Solobodan Ivković for his advice and to the reviewers Zsolt Gergely Szövényi and Péter Palatitz for their useful comments and improvements. The research was supported by the Hungarian Academy of Sciences (Bolyai János Research Fellowship: BO/00473/00) and by BioRes Limited Partnership.

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