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NOTES ON ORTHOPTERA (INSECTA) AND THEIR ASSEMBLAGES IN THE ROMANIAN CARPATHIANS

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Abstract. The Carpathian Mountains, particularly the Eastern Carpathians, represent an area with a high diversity and endemism in grasshoppers and bush-crickets. The well-preserved mountain grassland habitats are populated by diverse orthopteran assemblages. During the second half of July 2013, we visited 24 sites in Romanian Carpathians within altitudes ranging from 237 to 1700 m a.s.l. and found 71 Orthoptera species (36 Ensifera and 35 Caelifera). These represent 37.3% of the 190 species known to occur in Romania. Nine Carpathian endemics (*Isophya stysi, Pholidoptera frivaldskyi, Pholidoptera transsylvanica, Miramella ebneri, Pseudopodisma transilvanica, Isophya harzi, Isophya nagyi, Isophya sicula, Zubovskya banatica*), of which the last four are endemic to Romania and Eastern Carpathians, were recorded. Four environmental characteristics, i.e. habitat type, altitude, mean temperature and precipitation on sampled sites, are used to examine the structure of orthopteran assemblages by using DCA. Also, more detailed information on the occurrence of rare and endemic species is given.

Résumé. Les Carpates, en particulier les Carpates Orientales, représentent une zone avec une grande diversité et endémisme chez les sauterelles et les grillons. Les habitats de prairie de montagne bien conservés sont peuplés par divers associations d'orthoptères. Au cours de la seconde moitié de Juillet 2013, nous avons visité 24 sites dans les Carpates roumains dans des altitudes variant de 237 à 1700 m et où 71 espèces orthoptères (36 Ensifera et 35 Caelifera) ont été trouvées. Celles-ci représentent 37,3% des 190 espèces connues en Roumanie. Neuf espèces endémiques des Carpates (*Isophya stysi, Pholidoptera frivaldskyi, Pholidoptera transsylvanica, Miramella ebneri, Pseudopodisma transilvanica, Isophya harzi, Isophya nagyi, Isophya sicula, Zubovskya banatica*) ont été rapportées, dont les quatre dernières sont endémiques de la Roumanie et des Carpates Orientales. Quatre caractéristiques environnementales, à savoir le type d'habitat, l'altitude, la température moyenne et les précipitations sur les sites échantillonnés, sont utilisées pour examiner la structure des associations d'orthoptères en utilisant DCA. Aussi, on donne des informations plus détaillées sur la présence d'espèces rares et endémiques.

Key words: bush-crickets, grasshoppers, biodiversity, endemism, Carpathian Mountains, insect conservation.

INTRODUCTION

The Carpathian Mountains are an important center of endemism and biodiversity for several animal groups, including Orthoptera (Kenyeres et al., 2009; Nagy, 2005; Rácz, 1998; Storozhenko & Gorochov, 1992). Grasshoppers and bush-crickets (Orthoptera s.l.) are suitable indicators of grassland management types (Fabriciusová et al., 2011) and forest clearcuts in mountain landscapes (Sliacka et al., 2013). The montane landscape of the Carpathian Mountains has been shaped by historical migration routes of humans and animals as well as the specific glacial history (Kenyeres et al., 2009). Grassland habitats of the Romanian Carpathians are the best preserved of the entire Carpathian arch, being a regional hotspot for E and SE European orthopteran fauna (Kis, 1980; Rácz, 1998; Nagy, 2005; Kenyeres et al., 2009). Several species of European importance (e.g. *Pholidoptera transsylvanica* (Fischer), *Isophya harzi* Kis, *Isophya stysi* Cejchan, *Odontopodisma rubripes* (Ramme)) (Nagy, 2005; Krištín & Kaňuch, 2013) and Carpathian endemics have

significant populations occurring here. However, data on their biology and ecology are scarce, e.g. *Isophya* sp., *Zubovskya banatica* Kis, *Podismopsis transsylvanica* Ramme, *Pseudopodisma transilvanica* Galvagni & Fontana (Iorgu, 2012; Iorgu & Iorgu, 2010; Iorgu et al., 2008; Orci et al., 2010; Szövényi et al., 2012). In this area, the Orthoptera were studied since the 19th century (e.g. Fuss, 1855), faunistic data being rather regularly updated (e.g. Knechtel & Popovici-Bâznoşanu, 1959; Kis & Vasiliu, 1970; Iorgu et al., 2008). Recently, several new species have been described (e.g. for *Isophya* sp, see Iorgu & Iorgu, 2010; Orci et al., 2010; Iorgu, 2012; Szövényi et al., 2012).

On the other hand, quantitative or semi-quantitative data, even on rather common species, are still missing in this area. Hence, in this paper 1) we present findings of Orthoptera species from 24 sites in Romanian Carpathians collected in mid-summer aspect and 2) we explore the structure of orthopteran assemblages with regard to environmental and climatic variables on these sites.

MATERIAL AND METHODS

Data collection

Orthoptera were collected along the entire Romanian Carpathian region, mainly in known sites (I. Ş. Iorgu, unpublished) of some Carpathian endemic species (e.g. *Pholidoptera frivaldskyi* (Herman)). We focused on these sites because we study the phylogeography of this species. Altogether, 24 sites along an altitudinal gradient ranging from 230 to 1700 m a.s.l. (45°00'–47°34'N; 22°10'–26°42'E) (Fig. 1) were sampled. Qualitative and semi-quantitative survey of the Orthoptera assemblages was concentrated during five days, from the 16th to 21st of July 2012. The material was sampled mostly by sweeping herbal vegetation and partially the shrub vegetation

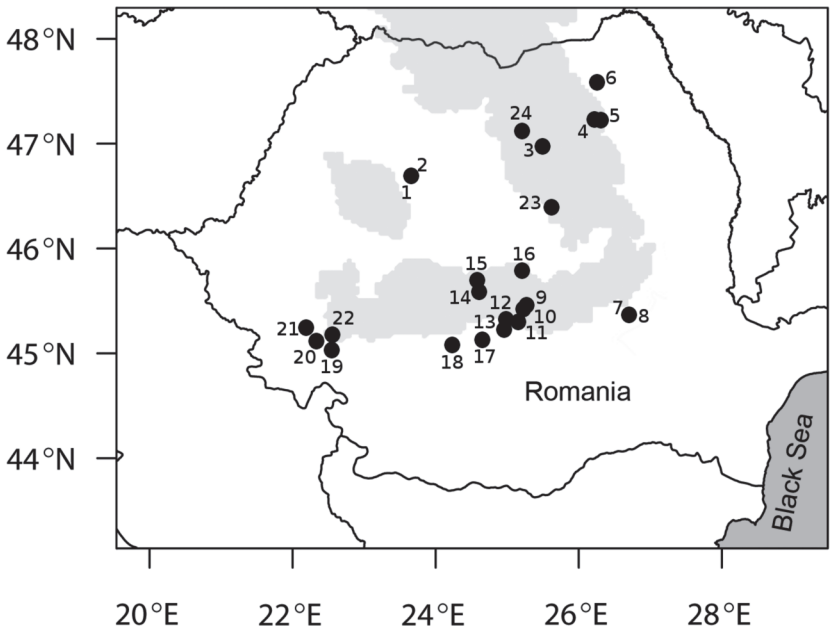

Fig. 1 - Outline of 24 study sites in Romanian Carpathian Mountains (black dots = sites; site numbers see Methods; lines = country borders, grey = alpine bioregion area in Carpathian Mountains).

by three or five samplers. This method was supplemented with individual collection and acoustic identification of specimens along selected transects and plots, covering characteristic habitats within the site. We spent approximately two hours of collection at each site. The relative abundance of individual species on the studied plots was expressed by using the following semi-quantitative ordinal scale: *1* – very rare (less than 3 adult specimens), *2* – rare (3–10 specimens), *3* – abundant (11–100 specimens), *4* – very abundant (more than 100 specimens). The material was identified directly in the field, but specimens with difficult identification were fixed in 75% alcohol and identified in the laboratory using identification keys (e.g. Harz, 1969; Harz, 1975; Heller et al., 2004; Kočárek et al., 2005). The data about the zoogeographic origin, habitat requirements and species area distribution were made according to Ingrisch & Köhler (1998), Rácz (1998), Iorgu et al. (2008). Habitat types were categorized post hoc to four main groups: I) meadows (M) = well preserved mown and/or unmown grasslands, with scattered shrub/ tree vegetation, II) meadows with forest edge (ME) = well preserved mown and/or unmown grasslands with sampled forest edge, III) ruderalized habitats (R) = ruderalized plots of different origin, IV) pastures (P) = regularly grazed pastures particularly with scattered shrub/tree vegetation. Long-term climate characteristics employed in the study were compiled from the WorldClim current climate dataset (Hijmans et al., 2005). We used annual mean temperature and annual precipitation as bioclimatic variables in a GIS-based raster format with a spatial resolution of ca. 1 km^2. Annual mean temperature of the sampled sites ranged from 2.4 to 10.0°C and annual precipitation from 579 to 968 mm.

Data analysis

The species-by-sample matrix was analyzed using a detrended correspondence analysis (DCA), by using default options with down-weighting of rare species, in order to explore orthopteran assemblages' patterns, i.e. association between species and post-hoc correlation of species abundance with altitude, annual mean temperature, annual precipitation, and four habitat types (see above and table 1). No transformation of species data was made, due to log-like nature of the ordinal scale used for assessing species abundance. Normality of the environmental variables (used as passive 'supplementary variables' in the DCA) was assessed by the Shapiro-Wilk test. As the test confirmed the normal distribution of the variables, no transformation was made. Kruskal-Wallis ANOVA was used to compare number of species among the four types of habitats; Brown-Forsythe test was used to test for equality of species number variance among habitats. Venn diagram was used to partition the species pool among the four habitat types. All statistical treatments were performed with software CANOCO 4.5 (Microcomputer Power, USA; Ter Braak and Šmilauer, 2002) and Statistica 7 (StatSoft, USA).

Short description of studied sites

1. Vâlcele 1 (46°40'32"N, 23°38'37"E): R; abandoned arable land between road and maize fields with partially preserved mesophytic and hygrophilous grasses and herbs (20–100 cm high) and dispersed shrub vegetation (*Salix* spp., *Rubus* spp.); the site is situated in the vicinity of Vâlcele village (546 m a.s.l., 2 ha);

2. Vâlcele 2 (46°41'19"N, 23°38'45"E): ME; grasslands along oak hornbeam forest edge and old orchards on S, SW slopes ca. 700 m E of "Vâlcele 1" site (661 m a.s.l., 2 ha);

3. Borsec Pass (46°57’38”N, 25°29’23”E): ME; grassland nearby a parking place with sparse and short mountainous grassy and herbaceous vegetation with dispersed *Rubus* and *Salix* spp., surrounded by spruce forests; located in Călimani Mountains, ca. 5 km W from Borsec village (1105 m a.s.l., 2 ha);

4. Vânători Neamţ 1 (47°13’50.83”N, 26°12’59.95”E): P; regularly grazed pastures with 10-50 cm high vegetation within open oak (*Quercus* sp.) woodland between the road and a closed oak forest (0.8 km E from Leghin village) (470 m a.s.l., 3 ha);

5. Vânători Neamţ 2 (47°13’18”N, 26°16’41”E): R; river gravel bank and wide bed of the river Ozana with sparse mostly ruderalized vegetation; ca. 0.3 km W of Vanatori Neamt village (418 m a.s.l., 2 ha);

6. Suceava - Bosanci (47°34’41.85”N, 26°15’41.93”E): P; pastures and partially ruderalized grasslands in the middle of fields (alfalfa, maize and corn) along a creek with fragmented hygrophilous vegetation (*Phragmites* spp., *Salix* spp.), ca. 2.6 km SW of the Bosanci village (357 m a.s.l., 2 ha);

7. Beciu Muddy Volcanoes (45°21’34.71”N, 26°42’46.93”E): M; xerothermic grassland with scattered trees around eroded muddy volcanoes with sparse and low (up to 20 cm) grassy and herbaceous vegetation; 1.9 km SE of the Beciu village (337 m a.s.l., 2 ha);

8. Beciu grasslands (45°21’36”N, 26°42’50”E): M; xerothermic meadows with dispersed shrub (*Crataegus, Rubus*) and tree vegetation (*Quercus, Pinus, Hippophae rhamnoides*) on W slopes, ca. 0.8 km NW of the previous Beciu muddy volcanoes site; (337 m a.s.l., 2 ha);

9. Giuvala Pass (45°27’24.42”N, 25°16’31.80”E): ME; traditionally used mountain meadows along fragmented beech forest edges in the Eastern part of Piatra Craiului Mountains, with well-preserved grassy and herb vegetation (with dispersed *Salix*) on S, SW slopes, ca. 1.5 km SW from Drumul Carului traditionally farming area (1182 m a.s.l., 2 ha);

10. Podul Dâmboviţei (45°24’25.90”N, 25°13’33.91”E): ME; similar habitats to previous site, located in a valley in the Eastern part of Piatra Craiului Mountains, ca. 8 km SW from Giuvala Pass (920 m a.s.l., ca. 2 ha);

11. Câmpulung - Valea Mare (45°17’32.21”N, 25°08’17.62”E): M; mown and partially ruderalized grasslands with scattered bushy and tree vegetation on the edge of a mixed beech forest, 5–6 km Northeast from Câmpulung town (880 m a.s.l., ca. 2 ha), nearby a Mausoleum;

12. Cândeşti (45°19’07.60”N, 24°58’49.21”E): M; grasslands and pastures on the embankments of Brătioara creek, surrounded by traditionally used mosaic landscape with mown meadows and old orchards on the SE edge of the Cândeşti village (675 m a.s.l, ca. 2 ha);

13. Berevoeşti (45°13’10.65”N, 24°56’59.7”E): M; mown grasslands in abandoned apple and plum orchards; ca. 1 km E of the Berevoeşti village (525 m a.s.l., ca. 2 ha);

14. Transfăgărăşan (45°34’36”N, 24°36’58”E): P; pastures between the sites Robaia (pastures with orchards) and Râul Capra (pastures in mountain spruce forest) along the Transfăgărăşan road (1000 m a.s.l., 3 ha);

15. Cârţişoara (45°41’24”N, 24°34’22”E): R; ruderalized xerophytic grasslands and pastures with dispersed shrubs (mainly *Rubus*) and trees along a creek, ca. 3.5 km N of the Cârţişoara village (560 m a.s.l., ca. 3 ha);

16. Perşani (45°46'59"N, 25°12'20.25"E): R; ruderalized grasslands surrounded by alfalfa, cereal and maize fields; ca. 0.3 km W from Perşani village (505 m a.s.l., ca. 2 ha);

17. Curtea de Argeş (45°07'04.21"N, 24°38'08"E): P; xerophytic pastures within dispersed orchards along beech forest edge, ca. 1.5 km E of the town Curtea de Argeş (500 m a.s.l., ca. 2 ha);

18. Govora (45°05'12"N, 24°13'26.60"E): R; ruderalized grasslands with dispersed orchards in the E edge of the Govora village (240 m a.s.l., ca. 2 ha);

19. Cracu Mare Pass (45°00'34"N, 22°31'19"E): ME; irregularly grazed mountain grassland with short mountainous grassy and herbaceous vegetation (<20 cm high) along beech forest edge; the site is located within the pass nearby the N entrance to Cerna - Domogled NP; ca. 5 km SW from Cracu Mare village (928 m a.s.l., ca. 2 ha);

20. Poarta Orientală Pass (45°05'47"N, 22°18'58"E): R; ruderalized grasslands in abandoned apple orchards along the main road; ca. 3 km N of the Domaşnea village (525 m a.s.l., ca. 2 ha);

21. Brebu Nou (45°14'12"N, 22°10'20.05"E): M; traditionally used mountain meadows in the Eastern part of the Banat Mts. (with dispersed *Rubus, Pinus*) on S, SE slopes, ca. 1.5 km Northeast from Brebu Nou traditionally farming area (995 m a.s.l., 2 ha);

22. Semenic Mountain (45°10'21"N, 22°31'51"E): ME; meadows on edges of fragmented beech forests in the surroundings of Semenic Mt.; ca. 1.5 km SW from the previous site (1415 m a.s.l., 2 ha);

23. Harghita-Ciceu Mountains (46°23'18.82"N, 25°38'38.50"E): M; mountain meadow, result of an old forest clear-cut, ca. 0.1 km E of Harghita Băi (1260 m a.s.l., ca. 0.5 ha);

24. Călimani Mountain (47°6'43.58"N, 25°12'46.67"E): M; subalpine meadows with *Rubus*, *Rumex*, *Veratrum*, *Juniperus*, *Pinus* etc., ca. 10 km W of Gura Haitii village, above the sulfur quarry (1700 m a.s.l., ca. 1 ha).

RESULTS AND DISCUSSION

Structure and zoogeographic patterns of orthopterans

Altogether, 71 Orthoptera species (36 Ensifera and 35 Caelifera species) were identified, with a rate of 7–25 species per site (Tab. 1). These species belong to four families and 38 genera, and represent 37.3% of the 190 species known to Romania. Among these species, there are nine Carpathian or East Carpathian endemics (Iorgu et al., 2008; Orci et al., 2010; Szövényi et al., 2012): five Carpathian endemics and four Eastern Carpathian or Romanian endemics (see table 1). From these endemic species, *P. frivaldskyi* was the most frequent (46% of the 24 studied sites); however, this was strongly biased by our focus to sample in particular sites of this species (Kaňuch et al., in prep.).

The most frequent and abundant orthopteran species at sampled sites were: the generalist Eurosiberian species – grasshopper *Chorthippus parallelus* (Zetterstedt) (frequency 100%) and the bush-cricket *Metrioptera bicolor* (Philippi) (79%). Regularly, *Metrioptera roeselii* (Hagenbach), *Euthystira brachyptera* (Ocskay), *Chorthippus brunneus* (Thunberg) (each of them with 54%), *Leptophyes albovittata* (Kollar), *Chorthippus biguttulus* (Linnaeus), and the South European grasshopper *Euchorthippus declivus* (Brisout de Barneville) occurred at sites, each of them with 46%. Furthermore, other species were rather frequent and abundant,

Table 1

Grasshoppers and crickets (Orthoptera), mantids (Mantodea), and environmental variables and zoogeographic range in 24 Carpathian sites in Romania (sites, see Methods and fig. 1, for habitats, see Methods, abundance: 1 very rare = less than 3 individuals, 2 rare = 3–10 ind., 3 abundant = 11–100 ind., 4 very abundant = more than 100 ind./ ha, f% = frequency within sites; zoogeographic range: Af = African (Etiopian), As = Asian, C = Central, Car = Carpathian, Cos = Cosmopolitan, E = East, En = Endemic, Eu = European, N = North, S = South, Si = Siberian, W = West).

Site No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
Habitat	R	ME	ME	P	R	P	M	M	ME	ME	M	M	M	P	R	R	P	R	ME	R	M	ME	M	M		
Altitude	546	661	1105	470	418	357	337	337	1182	920	880	675	525	1000	560	505	500	240	928	525	995	1415	1260	1700		
Annual mean temperature (°C)	8.2	7.5	4.7	7.4	7.6	8	9	9	5.1	6.3	6.2	7.7	8.5	4.1	8	8.3	8.9	10	7.2	9.2	6.8	5.2	4.2	2.4		
Annual precipitation (mm)	616	664	752	593	579	594	586	586	845	780	781	696	659	873	664	618	645	603	836	726	892	968	778	906	F%	Zoog. range
ENSIFERA																										
Phaneroptera falcata (Poda, 1761)	1	3						3									2			3	3				25.00	Eu-Si
Phaneroptera nana Fieber, 1853		2					1																		8.33	S Eu
Leptophyes albovittata (Kollar, 1833)	3	3		3				3			2	2	4	2		3		3		2					45.83	Eu
Isophya rectipennis Brunner von Wattenwyl, 1878								1																	4.17	SE Eu, W As
Isophya harzi Kiss, 1960									3																4.17	En
Isophya modesta modesta (Frivaldsky, 1867)		1																							4.17	C-SE-Eu
Isophya modestior Brunner von Wattenwyl, 1882																					2				4.17	N-E Carp
Isophya nagyi Szövényi, Puskás & Orci, 2012																								3	4.17	En
Isophya pienensis Mařan, 1954			2																						4.17	C-SE-Eu
Isophya sicula Orci, Szövényi & Nagy, 2010																							3		4.17	En
Isophya stysi Cejchan, 1958		2																							4.17	N-E Carp
Poecilimon thoracicus (Fieber, 1853)																				3					4.17	SE Eu, W As
Poecilimon fussii Brunner von Wattenwyl, 1878						3		4					4												12.50	SE Eu
Polysarcus denticauda (Charpentier, 1825)		2																							4.17	C-SE-Eu
Conocephalus fuscus (Fabricius, 1793)	1	1				3	4	1				3	4				3	3							37.50	Eu-Si
Conocephalus hastatus (Charpentier, 1825)																				4					4.17	SE Eu, W As
Ruspolia nitidula (Scopoli, 1786)	1	1				1	2	1					3			4	1	3							37.50	Af Eu-Si
Tettigonia cantans (Fuessly, 1775)	1			2																		1			12.50	Eu-Si
Tettigonia viridissima (Linnaeus, 1758)		2							2						1	2									16.67	Eu-Si
Tettigonia caudata (Charpentier, 1845)		3				2																			8.33	C-E-Eu
Decticus verrucivorus (Linnaeus, 1758)	3	3	1	2					1	2						3			3		4	3			41.67	Eu-Si
Metrioptera bicolor (Philippi, 1830)	4	4		4	3	4	4	4	4		2	2	4	4	2	3	2	4	2	2	3				79.17	Eu-Si
Metrioptera roeselii (Hagenbach, 1822)	4	3	3	4		2				2	2	2			2			2		3	3	1			54.17	Eu
Platycleis albopunctata grisea (Fabricius, 1781)							3																		4.17	C-SE-Eu
Platycleis veyseli (Kocak, 1984)							1						1		1										12.50	C-SE-Eu
Pholidoptera frivaldskyi (Herman, 1871)	3			3		2		3	3	3	3	3	2	2				2							45.83	N-E Carp
Pholidoptera griseoaptera (De Geer, 1773)		2																					3	2	12.50	Eu
Pholidoptera littoralis (Brunner von Wattenwyl, 1861)			3						1					3			3	2	4	4	3				33.33	SE Eu
Pholidoptera fallax (Fischer, 1853)																					3				4.17	S Eu
Pholidoptera transsylvanica (Fischer, 1853)									3	3	2	1											3	3	25.00	N-E Carp
Pterolepis germanica (Herrich-Schaffer, 1840)							1	4																	8.33	S Eu
Pachytrachis gracilis (Brunner von Wattenwyl, 1861)							1													3					8.33	SE Eu
Onconotus servillei Fischer von Waldheim, 1846								1																	4.17	SE Eu, W As
Ephippiger ephippiger (Fiebig, 1784)								1									2	2		2	2				20.83	C-E-Eu

Table 1 (continued)

Site No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
Habitat	R	ME	ME	P	R	P	M	M	ME	ME	M	M	M	P	R	R	P	R	ME	R	M	ME	M	M		
Altitude	546	661	1105	470	418	357	337	337	1182	920	880	675	525	1000	560	505	500	240	928	525	995	1415	1260	1700		
Annual mean temperature (°C)	8.2	7.5	4.7	7.4	7.6	8	9	9	5.1	6.3	6.2	7.7	8.5	4.1	8	8.3	8.9	10	7.2	9.2	6.8	5.2	4.2	2.4		
Annual precipitation (mm)	616	664	752	593	579	594	586	586	845	780	781	696	659	873	664	618	645	603	836	726	892	968	778	906	F%	Zoog. range
Gryllus campestris Linnaeus, 1758	1	3		1					1						2				2	2	2				33.33	Af Eu, W As
Oecanthus pellucens (Scopoli, 1763)								3										3		1					12.50	S Eu
CAELIFERA																										
Tetrix tuerki (Krauss, 1876)					1																				4.17	Eu
Pezotettix giornae (Rossi, 1794)							2	4	2			3	4				4	4		4					33.33	S Eu
Calliptamus italicus (Linnaeus, 1758)		2					4													1					12.50	Eu-Si
Miramella ebneri Galvagni, 1953																							2	2	8.33	N-E Carp
Pseudopodisma transilvanica Galvagni & Fontana, 1993			3			4			4																12.50	N-E Carp
Zubovskya banatica Kis, 1965																						3			4.17	En
Psophus stridulus (Linnaeus, 1758)													2										1	1	12.50	Eu-Si
Oedipoda caerulescens (Linnaeus, 1758)							3																		4.17	Eu-As
Sphingonotus caerulans (Linnaeus, 1767)					1		3																		8.33	Eu
Aiolopus thalassinus (Fabricius, 1781)							1																		4.17	Cos
Mecostethus alliaceus (Germar, 1817)	1					4																			8.33	Eu-Si
Stethophyma grossum (Linnaeus, 1758)	2			2																					8.33	Eu-Si
Euthystira brachyptera (Ocskay, 1826)	4	2	3	4		2			2						1		2		3		4	3	3	3	54.17	Eu-Si
Chrysochraon dispar (Germar, 1831)	3	1	2	3		2												2					1		29.17	Eu-Si
Stenobothrus rubicundulus (Germar, 1817)																					2				4.17	S Eu
Stenobothrus stigmaticus (Rambur, 1839)																						4	1	1	12.50	C-SE-Eu
Stenobothrus lineatus (Panzer, 1796)										2	3		3	2					3		4	2	2	2	37.50	Eu-Si
Stenobothrus nigromaculatus (Herrich-Schaffer, 1840)															1										4.17	Eu-Si
Omocestus (*Omocestus*) *viridulus* (Linnaeus, 1758)			2																				1	3	12.50	Eu-Si
Omocestus (*Omocestus*) *rufipes* (Zetterstedt, 1821)		3	3																3				1	1	20.83	Eu-Si
Omocestus haemorrhoidalis (Charpentier, 1825)		1			3		1					1													16.67	Eu-Si
Myrmeleotettix maculatus (Thunberg, 1815)					1																	3		1	12.50	Eu-Si
Gomphocerippus rufus (Linnaeus, 1758)												1												1	8.33	Eu-Si
Stauroderus scalaris (Fischer von Waldheim, 1846)																			4						4.17	Eu-Si
Chorthippus (*Glyptobothrus*) *apricarius* (Linnaeus,1758)			2			3																	2	2	16.67	Eu-Si
Chorthippus (*Glyptobothrus*) *biguttulus* (Ramme, 1942)	2	3		1	2	2				1		2									2	2	3	3	45.83	Eu
Chorthippus (*Glyptobothrus*) *brunneus* (Thunberg, 1815)	2	2		2	4	2						2	3		2	3		2	2		3	2			54.17	Eu-Si
Chorthippus (*Glyptobothrus*) *pullus* (Philippi, 1830)					1																				4.17	C-E-Eu, W As
Chorthippus oschei Helversen, O. von, 1986	3			2	3	3																			16.67	C-SE-Eu
Chorthippus albomarginatus (De Geer, 1773)			2																						4.17	Eu-Si
Chorthippus (*Chorthippus*) *dichrous* (Eversmann, 1859)																		1							4.17	Eu-Si
Chorthippus (*Chorthippus*) *dorsatus* (Zetterstedt, 1821)	2	2		2	2	2							2		2	2							1		37.50	Eu-Si
Chorthippus (*Chorthippus*) *montanus* (Charpentier, 1825)									3	2		1											1		16.67	Eu-Si
Chorthippus (*Chorthippus*) *parallelus* (Zetterstedt, 1821)	4	4	3	4	3	3	3	4	4	4	4	4	2	3	2	4	4	3	4	4	4	4	2	2	100.00	Eu-Si
Euchorthippus declivus (Brisout de Barneville, 1848)		3									4		4	3	2	4	3	4	2	3	2				45.83	S Eu
Total species per site	19	25	12	15	11	17	15	14	13	8	8	13	14	7	11	9	10	15	11	15	16	11	16	15		

e.g. the hygrophilous bush-crickets *Conocephalus fuscus* (Fabricius) and *Ruspolia nitidula* (Scopoli) (each of them 38%). The Mediterranean grasshopper *Pezotettix giornae* (Rossi), in previous papers given as rather rare (Iorgu & Pisică, 2006; Iorgu et al., 2008), and *Pholidoptera littoralis* (Fieber), an abundant SE European species, reached 33% frequency.

Regarding the zoogeographic distributional patterns, we found Orthoptera species from 14 zoogeographic areas (Rácz, 1998). As expected, the Eurosiberian species were the most frequent (38%), which form groups with seven other, mostly Central and SE European species, altogether 82% of all species (Tab. 1).

Assemblages along environmental and climatic gradients

Considering four habitat types, the median number of species tended to be the highest in meadows and the lowest in meadows with forest edges, however differences among habitat types were not statistically significant [$H (3, n = 24) = 1.267$, $P = 0.737$]. Furthermore, sites on meadows at forest edges had the largest range of species diversity (8–25 species), while only 7–19 species in other three habitat types. However, differences in species numbers' variances among habitat types were not statistically significant [$F (3, 20) = 0.611$, $P = 0.617$].

Separation of species along the first DCA axis (Fig. 2 A) can be attributed to their thermal preferences, as this axis is negatively correlated with annual mean temperature ($R = -0.843$) and positively with altitude ($R = 0.805$) and annual precipitation ($R = 0.576$; fig. 2 B). The species, e.g. *Poecilimon fussii* Brunner von Wattenwyl, *Oecanthus pellucens* (Scopoli), *Ephippiger ephippiger* (Fiebig), *Calliptamus italicus* (Linnaeus), *Pezotettix giornae* are generally more thermophilous and therefore found at lower altitudes, while e.g. *Pholidoptera transsylvanica, Chorthippus apricarius* (Linnaeus), and *Omocestus viridulus* (Linnaeus) are characteristic in higher altitudes. The second canonical axis is the most strongly correlated with annual precipitation ($R = 0.563$), indicated by species characteristic for higher altitudes, too. However, the species composition at particular sites may be influenced by local habitat heterogeneity, and some hygrophilous species can be therefore found also on generally xeric habitats with local hygrophilous parts (e.g. *Ruspolia nitidula, Conocephalus fuscus*) (cf. Detzel, 1998).

Distribution of sites differing in habitat type in the ordination space showed that there is not a clear pattern at the sites' species composition (Fig. 2 B). Eighteen of 71 sampled species (25.3%) were common for all the habitat types; most of them being eurytopic species (e.g. *Metrioptera bicolor*, *M. roeselii*, *Gryllus campestris* (Linnaeus), *Euthystira brachyptera*, *Chorthippus biguttulus*, *C. brunneus*, *C. dorsatus* (Zetterstedt), *C. parallelus*) and others expanding their range in Europe, e.g. *Ruspolia nitidula* (cf. Holuša at al., 2007) or *Pezotettix giornae* (cf. Kočárek, 1999). The Carpathian endemic *Pholidoptera frivaldskyi* was found in all types of habitat, while we did not expected it in ruderalized habitats.

On the other hand, seven species were present only in meadows and meadows with forest edges and another seven species were present only in ruderalized habitats, respectively. Pastures did not present any exclusive species (Fig. 3, Appendix 1). All seven species found on ruderalized habitats were rather rare species, which occurred only at one site and in low abundance (Appendix 1). 24 species were shared at least between two habitats. Therefore, it might be speculated that species diversity pattern can be affected more by larger-scale factors (e.g. by temperature, precipitation), or smaller-scale factors (e.g. vegetation height, forb and bare ground cover), than by local factors acting at the rather rough scale used in the present study, as the habitat

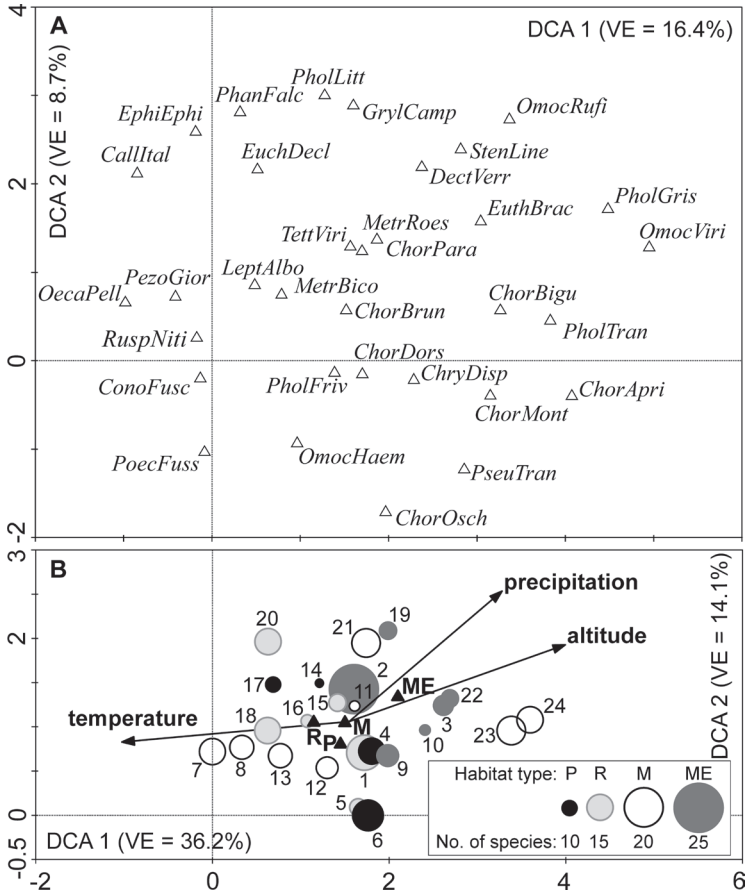

Fig. 2 - Detrended correspondence analysis of species-by-sample matrix of 24 sampled orthopteran assemblages in Romanian Carpathians: A, Species ordination diagram (only the species with highest weight (>3%) are displayed. Species names abbreviations are composed from the first four characters of their genus and species names. The full orthopteran names are given in table 1; B, Relation of altitude, annual mean temperature, annual precipitation (arrows), and four habitat types (centroids: see chapter Methods for abbreviations) at sampling sites (symbol size corresponds to the number of species per site and its color pattern to habitat type) [VE = variance explained (percentage variance) by particular axes of species data (A), and species-environment relation (B)].

type is (cf. Marini et al., 2009; Sliacka et al., 2013; Weiss et al., 2013). However, considering the descriptive and exploratory character of the present paper and relative small sample size, a more extensive research is needed to test this hypothesis.

Notes on rare species

The most remarkable, in terms of faunistics and zoogeography, are the endemic species *Zubovskya banatica*, *Isophya harzi*, *I. nagyi*, *I. sicula, I. stysi*, *Pholidoptera frivaldskyi, P. transsylvanica*, *Pseudopodisma transilvanica* and *Miramella ebneri*. Some rare were found, e.g. *Onconotus servillei* Fischer de Waldheim, *Isophya rectipennis* Brunner von Wattenwyl, *Poecilimon fussii*, *P. thoracicus* (Fieber), *Tetrix tuerki* Krauss, *Stauroderus scalaris* (Fischer de Waldheim).

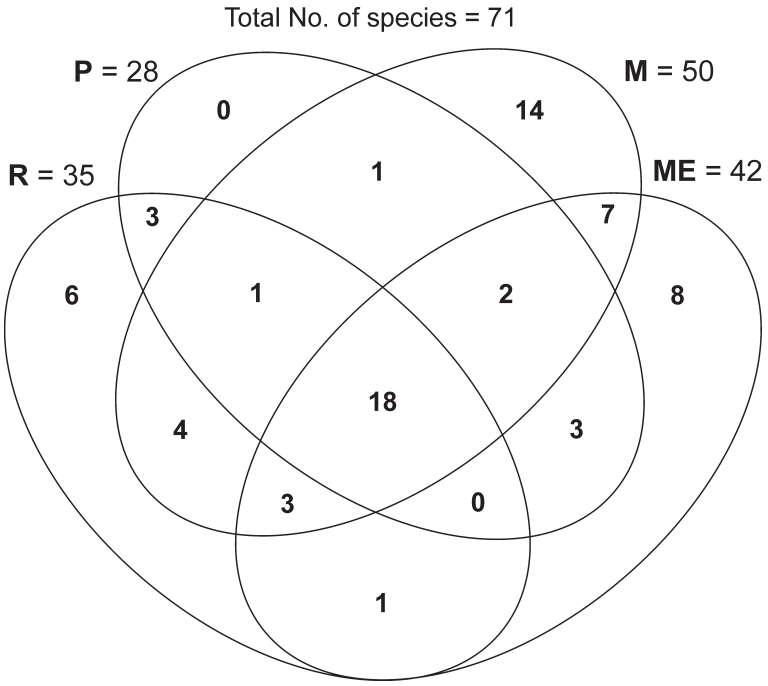

Fig. 3 - Partitioning of species among the four habitat types (for abbreviations see chapter Methods, for the list of species situated in particular segments see Appendix 1).

Zubovskya banatica – this species is endemic to the Semenic Mountains in Banat and was found in high population densities (>32 ♂♂, 26 ♀♀, 16 nymphs of 3-5th instar / 2 ha), in traditionally used meadows in fragmented beech forest in the area (1385–1400 m a.s.l.)

Isophya harzi – endemic, one of the few Orthoptera species listed in both IUCN Red List of Threatened Species and Annex II from Habitats Directive, occurs only in the Southern Carpathians. Listed as vulnerable in IUCN Red List (but it needs updating – see IUCN 2012). We found it only in one site (Giuvala pass in Făgăraş Mountains).

Isophya nagyi – this species, probably endemic to Călimani Mountains, was described only recently (Szövényi et al., 2012).

Isophya sicula - this bush-cricket has an interesting distribution area, described from Harghita-Ciceu Mountains (Orci et al., 2010) and found recently in Moldavian Subcarpathians, near Vânători-Neamţ (Iorgu, 2011).

Isophya stysi – a species of European importance (Annex IV, Habitats Directive), rare (1 male), was found only in ecotones of xerothermic forest steppes near the village Vâlcele. The species was found together with other thamnobiont species, such as *I. modesta* (2 ♂♂), *Polysarcus denticauda* (3 individuals), *Phaneroptera nana* (3 ♂♂).

Pholidoptera frivaldskyi – Carpathian endemic species was found at 11 sites (237–1190 m a.s.l.), in seven of them in relatively high abundance (>100 adults / 2 ha, see table 1). The high frequency of occurrence can be explained by our focus to sample mainly at sites of this species.

Pholidoptera transsylvanica – species of European importance (Annex IV, Habitats Directive). Similarly with the previous species, it is a Carpathian endemic species, found at six sites (670–1700 m a.s.l.), at several sites in relatively high abundance (>20 singing males / 2 ha). High altitude populations (5–10 males / 2 ha) in alpine grasslands near Cascada Capra (Făgăraş Mountains) and Călimani Mountains may be considered as the highest located populations of the species in Europe (also several other Romanian high Carpathian sites, above 1900 m a.s.l., I. Ş. Iorgu, unpublished).

Pseudopodisma transilvanica – this species is also endemic to the Carpathians, found at three sites (345–1190 m a.s.l.) in high abundance (>100 individuals / 2 ha). For taxonomical status of the genus *Pseudopodisma* within Carpathian Basin, see e.g. Nagy (2005).

Miramella ebneri – this grasshopper has a large distribution in the Carpathians, occurring on the subalpine meadows. In Northern Carpathians, the subspecies *Miramella ebneri carpathica* (Cejchan, 1958) may be found (also in Northern Romania: Rodnei Mountains).

Onconotus servillei – it is very conspicuous species of bush-cricket, due to its habitus with spiny pronotum. Listed as vulnerable in IUCN Red list (but it needs updating – see IUCN 2012), in Romania, it is extremely rare, inhabiting steppe meadows.

Isophya rectipennis – Balkan element, in Romania inhabits meso-xerophytic meadows in S and SE. During our studies, we found only one old female at Beciu grasslands (July 17, 2012), what is rather a late season for this species.

The Ponto-Pannonian species *Poecilimon fussii* was found at three sites, in high abundances (on July 16–18, 2012 approached to >100 individuals / 2 ha plots of herbaceous and shrubby vegetation (Suceava, Beciu grasslands and Berevoeşti).

The close-related Pontic species *P. thoracicus* was found only at one site (Pasul Poarta Orientală, in Banat area (on July 21, 2012, together only 3 ♀♀, 2 ♂♂ / 2 ha).

The specialized species *Tetrix tuerki*, with European distribution, is inhabiting gravel embankments of mountain rivers and creeks and it was found at only one site, on the banks of Ozana river (July 17, 2012).

Stauroderus scalaris – this Eurosiberian species, with fragmented populations in Europe, was found only at one site (Cracu Mare Pass, near Cerna-Domogled NP, 928 m a.s.l.). The population was very abundant (>100 individuals / 2 ha) and accompanied e.g. by strong populations of *Pholidoptera littoralis, Omocestus rufipes* and *Euchorthippus declivus*.

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NOTE ASUPRA ORTOPTERELOR (INSECTA) ŞI ASOCIERII LOR DIN ZONA CARPAŢILOR ROMÂNEŞTI

REZUMAT

Munţii Carpaţi, în special Carpaţii Orientali, reprezintă o zonă cu un grad înalt de diversitate şi endemism pentru lăcuste şi cosaşi. Habitatele de fâneţe montane sunt bine conservate şi populate de asociaţii de ortoptere diversificate. În timpul celei de a doua jumătăţi a lunii iulie 2012, am vizitat 24 situri din Carpaţii Românești, cu altitudini cuprinse între 237 şi 1700 m şi am colectat 71 specii de ortoptere (36 ensifere şi 35 caelifere). Acestea reprezintă 37,3% din cele 190 de specii cunoscute din România. Au fost identificate nouă endemisme carpatice (*Isophya stysi, Pholidoptera frivaldskyi,*

Pholidoptera transsylvanica, Miramella ebneri, Pseudopodisma transilvanica, Isophya harzi, Isophya nagyi, Isophya sicula, Zubovskya banatica), dintre care ultimele patru se găsesc numai în România. Structura asociațiilor de ortoptere a fost analizată folosind patru caracteristici de mediu: tipul de habitat, altitudinea, media temperaturilor și precipitațiilor anuale. De asemenea, au fost detaliate informațiile despre prezența ortopterelor rare și endemice.

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Appendix 1.

Species common for all the habitats: 18 - *Phaneroptera falcata*, *Leptophyes albovittata*, *Conocephalus fuscus*, *Ruspolia nitidula*, *Decticus verrucivorus*, *Metrioptera bicolor*, *Metrioptera roeselii*, *Pholidoptera frivaldskyi*, *Pholidoptera littoralis*, *Gryllus campestris*, *Pezotettix giornae*, *Euthystira brachyptera*, *Chrysochraon dispar*, *Chorthippus biguttulus*, *Chorthippus brunneus*, *Chorthippus dorsatus*, *Chorthippus parallelus*, *Euchorthippus declivus*;

Species occurring only in R (ruderal): 6 - *Poecilimon thoracicus, Conocephalus hastatus*, *Tetrix tuerki*, *Stenobothrus nigromaculatus*, *Chorthippus pullus*, *Chorthippus dichrous*;

Species occurring only in P (pastures): 0;

Species occurring only in M (meadows): 14 - *Isophya rectipennis*, *Isophya modestior*, *Isophya nagyi*, *Isophya sicula*, *Platycleis albopunctata grisea*, *Pholidoptera fallax*, *Pterolepis germanica*, *Onconotus servillei*, *Miramella ebneri*, *Psophus stridulus*, *Oedipoda caerulescens*, *Aiolopus thalassinus*, *Stenobothrus rubicundulus*, *Gomphocerippus rufus*;

Species with occurrence only in ME (meadow with forest edge): 8 - *Isophya harzi, Isophya modesta*, *Isophya pienensis, Isophya stysi*, *Polysarcus denticauda*, *Zubovskya banatica*, *Stauroderus scalaris*, *Chorthippus albomarginatus*;
Species common only for (shared only with) M and ME: 7 - *Phaneroptera nana*, *Pholidoptera griseoaptera*, *Pholidoptera transsylvanica*, *Stenobothrus stigmaticus*, *Omocestus viridulus*, *Omocestus rufipes*, *Chorthippus montanus*;
Species common only for (shared only with) R and P: 3 - *Mecostethus alliaceus, Stethophyma grossum, Chorthippus oschei*;
Species common only for (shared only with) P and M: 1 - *Poecilimon fussii*;
Species common only for (shared only with) R and ME: 1 - *Tettigonia viridissima*;
Species common only for (shared with) R and M: 4 - *Platycleis veyseli*, *Pachytrachis gracilis*, *Oecanthus pellucens*, *Sphingonotus caerulans*;
Species common for (shared with) R, P and M: 1 - *Ephippiger ephippiger*;
Species common for (shared with) P, M and ME: 2 - *Stenobothrus lineatus, Chorthippus apricarius*;
Species common for (shared with) R, P and ME: 0;
Species common for (shared with) R, M and ME: 3 - *Calliptamus italicus*, *Omocestus haemorrhoidalis*, *Myrmeleotettix maculatus*.