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Relationship between microclimate and Orthoptera assemblages in different exposures of a dolina

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Zusammenfassung

Wir haben den Zusammenhang zwischen den mikroklimatischen Verhältnissen und den Orthopteren-Gesellschaften einer Karstdoline im Aggteleker Nationalpark (N-Ungarn) in den Jahren 1998-99 untersucht. Die Werte der Lufttemperatur und relativen Luftfeuchtigkeit zeigen keinen signifikanten Zusammenhang (Spearman's Rangkorrelation) zu den Parametern der Orthopteren-Gesellschaften (Artenzahl, Individuenzahl, Shannon's Art/Frequenz-Diversität, Gleichmäßigkeit, effektive Artenzahl, Proportion der Ensifera, Faunenelemente, Lebensformtypen). Wir haben deshalb einen Gradient-Index entwickelt, welcher mit einer Zahl die Mikroklima innerhalb einer bestimmten Zeitspanne repräsentiert. Der Index zeigt die relative Rate der positiven bzw. negativen Temperaturgradient-Typen (Temperatur Gradient Index) und der relativen Luftfeuchtigkeit (Humidität Gradient Index). So konnten wir in beiden Jahren einen signifikanten Zusammenhang zwischen den Eigenschaften der Orthopteren-Gesellschaften bzw. dem Temperatur Gradient Index nachweisen.

Abstract

We studied the relationship between Orthoptera assemblages and microclimate in different exposures of a dolina in the Aggtelek National Park (NE Hungary) in 1998 and 1999. Using Spearman rank correlation the basic statistics of air temperature and relative air humidity (daily minimum, maximum, mean and range of observation) did not show a significant correlation with community characteristics of Orthoptera (number of species, number of individuals, Shannon diversity, evenness, effective number of species, proportion of Ensifera, faunal types and life forms). We developed the Gradient Index (GI) which represents microclimate with a single number representing a certain time period. The index shows the relative rates of positive and negative gradient types of temperature (Temperature Gradient Index) and relative air humidity (Humidity Gradient Index). In both years we found a significant correlation between the community statistics of the Orthoptera assemblages and the Temperature Gradient Indices developed by us.

Introduction

Orthoptera are known as grass dwelling (herbicolous) insects with good indicative value. They are well adapted to their environment in their body shape (HARZ 1957), life forms (BEI-BIENKO 1939, HARZ 1957, PRAVDIN 1978), larval develop-

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ment and physiology (CHAPMAN 1959, HARZ 1957), and even in their behaviour (CHAPPEL & WHITMAN 1990) as well.
The thermal radiation has a powerful role in animal ecology causing patterns in different spatial and temporal scales (KELLY at al. 1954). The large scale relationship between climatic variation and zonation of Orthoptera assemblages of different altitudes have already been studied (e.g. DREUX 1962, CLARIDGE & SHINGRAO 1978). We hypothesised that the organisation of the Orthoptera assemblages is driven by the different microhabitat selection of the species and there is correlation between the measured or calculated climatic variables and the community characteristics of Orthoptera assemblages in such a small spatial scale as a dolina.

Material and methods

Study area, climatic measuring and sampling

The study area was a dolina located in the Aggtelek Karst (NE Hungary), right near the Hungarian-Slovakian border close to Jósvafő. The dolina is part of the Aggtelek National Park, and is a core area in the central part of the UNESCO MAB Reserve. The dimension of the dolina is 130 m by 80 m, its maximum depth is 10 m. In 1998 and 1999, we measured and sampled in seven different sites of the dolina, which are detailed in Table 1 (for the location see Fig. 1).

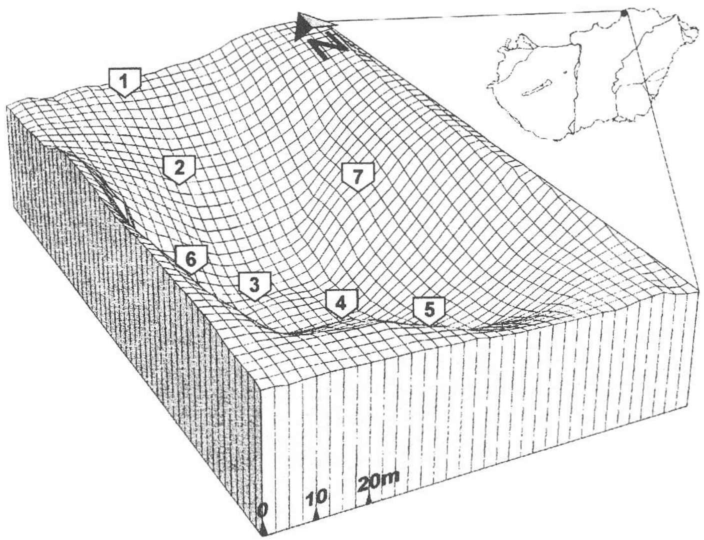

Fig. 1: Location of the dolina in the Aggtelek National Park (NE Hungary) with the measuring and sampling sites in it. See also Table 1.

Table 1 Exposition and inclination of the sampling sites. See also in Fig. 1.

Site	Exposition	Inclination
1	S	16°
2	S	13°
3	-	0°
4	N	9°
5	N	13°
6	S	25°
7	WSW	20°

The plant association in the dolina is mostly *Polygalo (majori)-Brachipodietum pinnati* that is characterised by tall grasses (100-120 cm) with many dicots in the lower grass-level (40-60 cm). It is the dominant grassland type of the mesic sites of dolinas on the higher plateaus of the Aggtelek Karst Area. On steep slopes of the dolina (site 6 and 7) the plant association is *Poo badensis-Caricetum montanae* (VARGA-SIPOS & VARGA 1996). This association with physical weathering and eluation is characterised by the presence of dolomit grassland species and short grasses. The soil is thin, rocky and light brown on the slopes and deep, humic and dark coloured in the bottom of the dolina.
The climatic observation was carried out from 13.00, 8. VIII. 1998 to 13.00 next day and 17.00, 28. VII. 1999 to 17.00 next day. The weather condition was clear, windless and contrasty in 1998 while it was almost cloudless, windless but not very contrasty in 1999. During the 24-hour measuring we used 3 pieces of dry- and wet-bulb thermometers (aspirated Assmann psichrometers) at 0, 0.2, 0.4 and 2 m heights (h) in seven points of the dolina as it is detailed above (Table 1, Fig. 1). We measured diurnal running of air temperature (T_h) and relative air humidity (H_h) in each heights (in site 4, 5, 6 the observations were carried out in even hours and in site 1, 2, 7 those of were carried out in uneven hours, site 3 was the reference point so we measured there each hours).
The sampling of Orthoptera was made around each climatic observation point in each of the two years. Concerning the different daily activity of the species we sampled twice during the climatic measures (9.00-12.00 and 14.00-17.00). The data of the two samplings were summarised in each year. The samples were taken simultaneously by both of the authors from square quadrates (25 m * 25 m) with 200 slaps (100 slaps per person) of a strong and large aperture sweep-net in each site. Most of the collected Orthoptera were identified in the field following the species keys of HARZ (1969, 1975). The percentage of larvae was less than 5% and all the adult individuals were identified to the species level. The identified animals were released after the sampling. As concerns the nomenclature we followed HELLER et al. (1998).

Data analyses

We calculated minimum, maximum, mean, range of air temperature and relative air humidity in each height (h) for each sites and time value (Table 2). Daily running of temperature and relative humidity differences between a given height and 2 m ($Tdiff_h$, $Hdiff_h$), characterising the air temperature and relative air humidity gradients, was also calculated:

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$$T_h - T_{2m} = Tdiff_h \quad (1)$$

$$H_h - H_{2m} = Hdiff_h \quad (2)$$

When $Tdiff_h$ is above 0 °C the temperature gradient is positive (insolation type), when $Tdiff_h$ is below 0 °C the temperature gradient is negative (emission type) at the given height. When $Hdiff_h$ is above 0% the relative air humidity gradient is positive (wet type), when $Hdiff_h$ is below 0% the relative air humidity gradient is negative (dry type) at the given height.

The microclimate of a selected height can be well characterised by the ratio of positive and negative gradient types. This ratio invented by the authors is the Gradient Index (*GI*), and it can be calculated in the following ways:

$$GI1_h = P_h - N_h \quad (3)$$

$$GI2_h = \frac{P_h}{P_h + N_h} \quad (4)$$

Where P_h is the area beneath the $Tdiff_h(t)$ or $Hdiff_h(t)$ function curves during where $Tdiff_h(t)$ and $Hdiff_h(t)$ above zero, N_h is the area beneath the $Tdiff_h(t)$ or $Hdiff_h(t)$ function curves where $Tdiff_h(t)$ and $Hdiff_h(t)$ below zero during a 24 hour period (*t* means time). *GI*1 (equation 3) is the difference between the rates of positive (P_h) and negative (N_h) gradient types. Its value can either be positive or negative. *GI*2 (equation 4) is the relative rate of positive gradient type (P_h) compared to the whole area beneath the curve. *GI*2 ranges in the [0, 1] interval. The Gradient Index is a Temperature Gradient Index (*TGI*) if we use $Tdiff_h$ for calculation and a Humidity Gradient Index (*HGI*) if we use $Hdiff_h$.

The Gradient Indices (*GI*) can either be day or habitat specific depending on the aims of the study, the number of habitats and the measuring interval. If we measure microclimate at several sites at the same time we can compare the habitats, and this is the case here.

As community characteristic of the Orthoptera, the traditional Shannon diversity index was used (with natural logarithm). This index is more sensitive to the rare species than to the abundant ones. We also calculated the evenness and the effective number of species based on the Shannon diversity (TÓTHMÉRÉSZ 1995). The evenness gives information about the abundance structure of the assemblages. The effective number of species is the number of species, which would have the same diversity if they were all equally frequent. Diversity statistics were calculated by the DivOrd package (TÓTHMÉRÉSZ 1993).

Proportion of faunal types and life forms was calculated after RÁCZ (1993, 1998). Concerning life forms RÁCZ's work adopted the basic idea of PRAVDIN (1978) who defined species living in high and very dense grasses, shrubs and ecotones as thamnobionts, species living in grasses as chortobionts and ground dwelling species as geobionts. In case of species, which fail to match exactly one category we used intermediate categories like geo-chotobiont. We also calculated the proportion of Ensifera according to the taxonomy of the species.

We used Spearman rank correlation coefficient for testing the relationship between climatic data and community characteristics.

Table 2: Basic statistics of the climatic measures at the different sites and heights in 1998 and 1999.

1998		Air temperature (°C)				Relative air humidity (%)			
Site	Height	Min.	Mean	Max.	Range	Min.	Mean	Max.	Range
1	0.0	7.4	19.9	31.6	24.2	44	76	100	56
	0.2	7.2	18.6	30.0	22.8	47	79	100	53
	0.4	6.6	18.2	29.4	22.8	52	79	100	48
	2.0	7.6	18.7	28.0	20.4	44	75	100	56
2	0.0	6.8	18.9	31.2	24.4	54	83	100	46
	0.2	5.8	17.5	29.2	23.4	51	80	100	49
	0.4	5.4	17.4	28.4	23.0	49	80	100	51
	2.0	6.0	17.6	28.2	22.2	46	78	100	54
3	0.0	5.0	16.5	27.4	22.4	76	90	100	24
	0.2	4.7	16.6	28.2	23.5	50	82	100	50
	0.4	5.3	16.8	28.7	23.4	49	80	100	51
	2.0	6.2	17.0	27.8	21.6	44	77	100	56
4	0.0	7.1	17.9	30.4	23.3	53	86	100	47
	0.2	5.8	16.9	28.6	22.8	54	83	100	46
	0.4	6.0	17.4	28.6	22.6	50	81	100	50
	2.0	6.6	17.5	27.4	20.8	48	78	100	52
5	0.0	6.4	17.5	29.8	23.4	58	84	100	42
	0.2	6.4	17.4	28.6	22.2	52	82	100	48
	0.4	8.0	18.0	27.0	19.0	48	81	100	52
	2.0	10.2	18.7	26.2	16.0	45	77	100	55
6	0.0	7.6	19.1	34.2	26.6	50	82	100	50
	0.2	6.8	17.7	29.2	22.4	51	81	100	49
	0.4	7.0	17.4	28.6	21.6	50	80	100	50
	2.0	6.6	17.4	28.2	21.6	51	78	100	49
7	0.0	6.0	19.1	31.6	25.6	57	83	100	43
	0.2	6.4	18.2	28.8	22.4	51	80	100	49
	0.4	6.6	18.2	29.0	22.4	47	78	100	53
	2.0	7.0	18.1	28.0	21.0	43	76	100	57
1999				Air temperature (°C)			Relative air humidity (%)		
Site	Height	Min.	Mean	Max.	Range	Min.	Mean	Max.	Range
1	0.0	10.4	17.6	27.2	16.8	65	89	100	35
	0.2	8.8	16.5	24.2	15.4	59	85	100	41
	0.4	9.6	16.9	23.2	13.6	60	80	100	40
	2.0	11.6	17.3	22.0	10.4	53	73	98	45
2	0.0	10.4	16.9	23.3	12.9	66	87	100	34
	0.2	9.2	16.6	24.0	14.8	62	84	100	38
	0.4	9.2	16.9	23.5	14.3	54	77	100	46
	2.0	9.6	17.1	22.6	13.0	54	74	100	46
3	0.0	10.0	15.5	21.6	11.6	86	96	100	14
	0.2	8.3	15.4	23.4	15.1	66	88	100	34
	0.4	8.0	16.0	22.9	14.9	56	80	100	44
	2.0	9.2	16.9	22.3	13.1	51	76	99	48
4	0.0	9.8	16.2	22.6	12.8	74	91	100	26
	0.2	8.8	16.3	24.2	15.4	63	86	100	37
	0.4	8.6	16.7	23.0	14.4	57	79	100	43
	2.0	10.6	17.1	22.6	12.0	54	72	100	46
5	0.0	10.2	16.4	25.0	14.8	63	85	100	37
	0.2	9.0	16.2	23.4	14.4	60	81	100	40
	0.4	11.6	17.0	23.2	11.6	50	77	100	50
	2.0	12.4	17.5	22.4	10.0	52	73	100	48
6	0.0	10.2	16.9	25.8	15.6	56	87	100	44
	0.2	9.4	16.8	23.1	13.7	61	77	98	37

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	0.4	10.4	17.2	22.6	12.2	54	76	98	44
	2.0	9.4	17.3	22.6	13.2	49	71	93	44
7	0.0	9.6	17.5	26.6	17.0	58	84	100	42
	0.2	9.6	17.0	24.6	15.0	60	81	100	40
	0.4	8.8	17.0	24.0	15.2	51	77	100	49
	2.0	11.0	17.4	23.0	12.0	51	72	94	43

Results

A total of 975 individuals belonging to 23 Orthoptera species (11 *Ensifera* and 12 *Caelifera*) were identified from sweep-net samples in the dolina in 1998 and 1999 (Table 3). One of them is an Eastern Carpathian ("Dacian") element *Pholidoptera transsylvanica* that is a protected species in Hungary.

The number of species and the number of individuals were higher in the S and WSW exposure. Their values were minimal in the bottom of the dolina. The species number was the highest in site 5 in 1998. This high number was probably caused by the edge of the dolina. Both Shannon diversity and evenness decreased from the lips to the bottom of the dolina (Table 4).

Most of the Orthoptera species of the dolina belong to two major faunal groups. The first is the Siberian group containing Siberian, Siberian-polycentric and Angarian elements (e.g. *Metrioptera brachyptera* and *Euthystira brachyptera* which are dominant). The other major group is the Mediterranean that is represented by Ponto-Caspian and Ponto-Mediterranean elements (e.g. *Leptophyes albovittata* and *Stenobothrus crassipes*). Besides these there are Balcanic-Ilyrian, Balcanic-Dacian and Dacian elements (e.g. *Isophya kraussi* and *Pseudopodisma nagyi*).

Concerning the individual numbers the Siberian group was dominant in all sampling sites and their ratio was lower on the lips than in the bottom of the dolina in both years (Table 4). The ratio of Balcanic and Dacian species were larger in North exposure (site 4 and 5) in 1998. In 1999 they had low ratios in all sites.

Considering the distribution of life forms the chortobiont ratio was very high in all sites. The ratio of transitional forms – chorto-thamnobiont and geo-chortobiont – were very low in all cases. The larger thamnobiont ratio could be observed in North exposure (Table 4).

The basic statistics of air temperature and relative air humidity reflect the morphology of the dolina and plant architecture at a given site (Table 2). Compared to this the Gradient Indices show the vertical microclimatic differences in relation to the microclimatic values at 2 m height (Table 5). The microclimate at 2 m is mostly independent of the surface morphology and plant architecture, while these latter effects influence the lower measures (0-0.4 m).

We found no correlation between any community statistics of the Orthoptera assemblages and basic statistics of air temperature and relative air humidity (daily minimum, maximum, mean and range). Comparing community data to Humidity Gradient Index (*HGI*) we could not find a correlation. We found several significant rank correlations between the community statistics of the Orthoptera assemblages and Temperature Gradient Indices (*TGI*1 and *TGI*2) in both years. In 1998 we found highly significant ($p<0.05$) positive correlation between the number of individuals and $TGI2_{0.0m}$ and highly significant ($p<0.05$) negative correlation between the proportion of thamnobiont life form and $TGI2_{0.2m}$. In 1999 the correlation was positive between the effective number of species and $TGI1_{0.0m}$, between the effective number of species and $TGI2_{0.0m}$, between the Shannon diversity and $TGI1_{0.0m}$ and between the Shannon diversity and $TGI2_{0.0m}$ at the $p<0.05$ significance level. We also found significant ($p<0.1$) correlation concerning Gradient Indices and evenness, the proportion of Ensifera, proportion of geo-chortobiont life style and the proportion of several faunal types (Table 6).

Table 3: Orthoptera of the different sampling sites of the dolina in 1998 and 1999. Faunal types and life forms after RÁCZ (1998):
An: Angarian; Ba: Balcanic; Ca: Caspian; Da: Dacian; Il: Illyrian; Med: Mediterranean; Pc: Policentric; Po: Pontic; Si: Siberian; Tur: Turchestanian;
Ch: Chorthobiont, Geo: Geobiont; Th: Thamnobiont.

1998	Site	1	2	3	4	5	6	7
Phaneroptera falcata (Poda, 1761)		0	1	0	0	0	0	0
Isophya kraussii Brunner von Wattenwyl, 1878		1	1	0	1	3	0	0
Leptophyes albovittata (Kollar, 1833)		1	1	1	1	2	2	0
Tettigonia cantans (Fuessly, 1775)		0	0	0	0	2	0	0
Decticus verrucivorus (Linnaeus, 1758)		0	0	0	0	0	0	0
Metrioptera brachyptera (Linnaeus, 1761)		12	10	3	9	4	6	12
Metrioptera bicolor (Philippi, 1830)		4	2	0	0	1	1	1
Metrioptera roeselii (Hagenbach, 1822)		0	0	0	0	0	0	0
Pholidoptera transsylvanica (Fischer, 1853)		0	0	0	0	1	0	0
Pholidoptera fallax (Fischer, 1853)		5	3	0	0	5	8	4
Pholidoptera griseoaptera (De Geer, 1773)		0	0	0	0	1	0	3
Pseudopodisma nagyi Galvani et Fontana, 1996		0	0	0	0	7	0	0
Psophus stridulus (Linnaeus, 1758)		1	2	0	0	3	0	1
Chrysochraon dispar (Germar, [1834])		0	2	0	2	1	0	0
Euthystira brachyptera (Ocskay, 1826)		61	84	36	25	18	74	43
Stenobothrus crassipes (Charpentier, 1825)		9	5	0	0	0	1	12
Stenobothrus lineatus (Panzer, 1796)		0	1	0	0	0	2	3
Chorthippus biguttulus (Linnaeus, 1758)		1	0	0	0	0	0	0
Chorthippus mollis (Charpentier, 1825)		0	0	0	0	1	0	0
Chorthippus parallelus (Zetterstedt, 1821)		6	9	3	1	2	0	1
Euchorthippus pulvinatus (Fischer de Waldheim,1846)		0	0	0	0	2	0	0
Gomphocerippus rufus (Linnaeus, 1758)		3	6	0	0	1	11	2
Tetrix bipunctata (Linnaeus, 1758)		4	0	0	0	0	1	1
	Sum	108	127	43	39	54	106	83

1999	Faunal type	Life forms	1	2	3	4	5	6	7
Phaneroptera falcata	Si-Pc	Th	2	0	0	1	2	2	1
Isophya kraussii	Ba-Il	Ch	1	1	0	0	1	0	1
Leptophyes albovittata	Po-Med	Th	1	1	0	1	8	2	1
Tettigonia cantans	Si	Th	0	1	0	0	1	0	1
Decticus verrucivorus	An	Ch-Th	0	0	0	1	1	0	0
Metrioptera brachyptera	Si-Pc	Ch	13	12	4	3	4	15	7
Metrioptera bicolor	An	Ch	4	0	0	1	0	0	2
Metrioptera roeselii	Po-Ca	Ch	4	1	1	0	0	0	0
Pholidoptera transsylvanica	Da	Ch-Th	0	0	0	0	0	0	1
Pholidoptera fallax	Po-Med	Ch	10	2	0	1	0	1	2
Pholidoptera griseoaptera	Po-Ca	Ch-Th	0	0	0	0	2	2	0
Pseudopodisma nagyi	Ba-Da	Ch	0	0	0	0	0	0	0

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Psophus stridulus	An	Geo-Ch	1	0	0	0	0	1	1
Chrysochraon dispar	An	Ch	0	0	0	0	0	0	0
Euthystira brachyptera	An	Ch	75	48	31	36	31	21	8
Stenobothrus crassipes	Po-Med	Ch	6	0	0	0	0	0	3
Stenobothrus lineatus	An	Ch	2	0	1	1	0	1	2
Chorthippus biguttulus	Po-Ca	Ch	0	0	0	0	0	0	0
Chorthippus mollis	An	Ch	0	0	0	0	0	0	0
Chorthippus parallelus	An	Ch	12	7	0	1	1	0	1
Euchorthippus pulvinatus	Po-Ca-Tur	Geo-Ch	0	0	0	0	0	0	0
Gomphocerippus rufus	An	Ch	0	0	0	0	0	0	0
Tetrix bipunctata	Si-Pc	Ch	0	0	0	0	0	0	1
		Sum	131	73	37	46	51	45	32

Table 4: Basic statistics of the studied Orthoptera assemblages in 1998 and 1999. Letters in parenthesis following the site numbers indicate the exposures.

1998	1 (S)	2 (S)	3 (-)	4 (N)	5 (N)	6 (S)	7 (WSW)
Number of species	12	13	4	6	16	9	11
Number of individuals	108	127	43	39	54	106	83
Effective number of species	4.9224	3.9347	1.8363	2.8794	9.9424	3.0813	4.8979
Shannon diversity	1.5938	1.3698	0.6077	1.0576	2.2968	1.1254	1.5888
Evenness	0.6414	0.5341	0.4384	0.5402	0.8284	0.5122	0.6626
Thamnobionts	0.0093	0.0157	0.0233	0.0256	0.0741	0.0189	0.0000
Chorto-thamnobionts	0.0000	0.0000	0.0000	0.0000	0.0370	0.0000	0.0361
Chortobionts	0.9815	0.9685	0.9767	0.9744	0.7963	0.9811	0.9518
Geo-Chortobionts	0.0093	0.0157	0.0000	0.0000	0.0926	0.0000	0.0120
Mediterranean faunal circle	0.1481	0.0709	0.0233	0.0256	0.1852	0.1038	0.2289
Siberian faunal circle	0.8426	0.9213	0.9767	0.9487	0.6111	0.8962	0.7711
Balcanic and Dacian type	0.0093	0.0079	0.0000	0.0256	0.2037	0.0000	0.0000
Proportion of Ensifera	0.2130	0.1417	0.0930	0.2821	0.3519	0.1604	0.2410

1999	1	2	3	4	5	6	7
Number of species	12	8	4	9	9	8	14
Number of individuals	131	73	37	46	51	45	32
Effective number of species	4.7471	3.0986	1.7931	2.5922	3.8776	4.0180	9.8478
Shannon diversity	1.5575	1.1309	0.5839	0.9525	1.3552	1.3908	2.2872
Evenness	0.6268	0.5439	0.4212	0.4335	0.6168	0.6680	0.8668
Thamnobionts	0.0229	0.0274	0.0000	0.0435	0.2157	0.0889	0.0938
Chorto-thamnobionts	0.0000	0.0000	0.0000	0.0217	0.0588	0.0444	0.0313
Chortobionts	0.9695	0.9726	1.0000	0.9348	0.7255	0.8444	0.8438
Geo-Chortobionts	0.0076	0.0000	0.0000	0.0000	0.0000	0.0222	0.0313
Mediterranean faunal circle	0.1603	0.0548	0.0270	0.0435	0.1961	0.1111	0.1875
Siberian faunal circle	0.8321	0.9315	0.9730	0.9565	0.7843	0.8889	0.7500
Balcanic and Dacian type	0.0076	0.0137	0.0000	0.0000	0.0196	0.0000	0.0625
Proportion of Ensifera	0.2672	0.2466	0.1351	0.1739	0.3725	0.4889	0.5000

Table 5: Temperature Gradient Indices (*TGI*1 and *TGI*2, for calculation see the text) of different heights on the seven sites in 1998 and 1999.

1998	1	2	3	4	5	6	7
$TGI1_{0.0m}$	15.8	17	-12.7	4.7	-15	21.8	11.9
$TGI1_{0.2m}$	-1.3	-2	-10	-8.1	-16.3	3.1	1.0
$TGI1_{0.4m}$	-5.6	-2.4	-4.3	-1.9	-8.7	-0.3	0.5
$TGI2_{0.0m}$	0.7883	0.8632	0.2756	0.5874	0.3057	0.8225	0.7228
$TGI2_{0.2m}$	0.4539	0.4194	0.3227	0.3099	0.2523	0.5917	0.5316
$TGI2_{0.4m}$	0.2667	0.3571	0.3971	0.4228	0.2395	0.4854	0.5221

1999	1	2	3	4	5	6	7
$TGI1_{0.0m}$	3.5	-3.4	-18.3	-12.5	-13.8	-5.3	1.9
$TGI1_{0.2m}$	-10.8	-6.1	-18.8	-10.4	-17	-5.5	-4.9
$TGI1_{0.4m}$	-6.2	-3.1	-11.5	-5.3	-6.1	-0.5	-5.2
$TGI2_{0.0m}$	0.5726	0.4045	0.0402	0.1469	0.2621	0.4007	0.5468
$TGI2_{0.2m}$	0.2923	0.3237	0.0766	0.2953	0.1239	0.3179	0.3828
$TGI2_{0.4m}$	0.2817	0.376	0.129	0.345	0.2479	0.4627	0.3267

Discussion

The compositional differences of the Orthoptera assemblages depend on the distribution of the biotic and abiotic environmental factors. Our data and results demonstrate horizontal (asymmetrical) and vertical (symmetrical) regularities of the orthopteran distribution patterns in the dolina. The horizontal pattern is caused by the different exposures of the sites. While the vertical pattern is effected by the night-time air stratification in the dolina (the air temperature can sink below zero in the summer). This was detectable even is such every-day climatic conditions and not in a bright and contrasty situation.

Abiotic environmental factors are very variable in a dolina concerning microclimate (JAKUCS 1954, BÁRÁNY 1967) and vegetation architecture (see Material and methods). Microclimate is the overall climatic property of a certain air-space that is different from surrounding air-spaces (BACSÓ 1970). As we showed, the differences among the sites in the dolina are not so discretely distributed, we prefer a more continuous definition of the microclimate both in time and space. On the basis of the latter definition we cannot measure different microclimates, but we can measure the microclimatic differences.

Microclimate and vegetation architecture often interact with each other (SÓLYMOS & NAGY 1997). This results in the similarities of the patterns of vegetation and grasshopper community composition (KEMP et al. 1990a, 1990b). The Gradient Index (*GI*) quantifies the microclimatic differences that are affected by the vegetation-climate interaction as well, consequently it properly characterise the differences of the habitat properties. Since Orthoptera are good indicator organisms (RÁCZ 1993, 1998) so the differences of their community statistics correspond to the habitat differences characterised by the Gradient Index.

It is hard to find a scalar quantity that is representative for a time sequence of an all day long microclimatic observation, while it is comparable with community characteristics of Orthoptera assemblages. Basic statistics of the measured continuous variables (e.g. daily minimum, maximum, mean and range of air temperature and relative air humidity considering certain periods) cannot characterise the diurnal running of temperature and relative air humidity alone. The mini-

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mum and maximum values are only the extreme values of the diurnal curves and the mean characterise the curve itself. As contrast the Gradient Indices (*GI*) represent the ratio of insolation type gradient that is in connection with the accumulated quality of radiation. Both basic statistics of climatic variables and the Gradient Indices (*GI*) are able to represent the microclimate of a given measuring height influenced by vegetation architecture and exposure.

The Humidity Gradient Index (*HGI*) did not show correlation because of the frequent occurrence of the 100% humidity value especially in 1999. The relative air humidity hardly depends on temperature and anemometric properties of the habitat.

The number of significant correlations using *TGI*1 and *TGI*2 is well balanced between the two years. In our opinion both of the two Gradient Indices are appropriate in characterising the differences among several habitats. We suggest to use the absolute (*TGI*1) and relative (*TGI*1) kind of Gradient Indices in order to the statistical properties of the data set (see e.g. ATCHLEY et al. 1976).

As concerns the vertical structure of the grassy habitats, the number of significant correlations decreased from 0.0 m to upwards. Using Temperature Gradient Indices (*TGI*) we found 9, 8 and 3 significant correlations at 0.0 m, 0.2 m and 0.4 m respectively (Table 6). Since most of the studied Orthoptera species dwell in the 0-20 cm level, accordingly our results are not artificial and reflects connection between microclimate and the spatio-temporal structure of the Orthoptera assemblages.

Contrary to this, completely different parameters were found to be significant in the two years (Table 6). So we can conclude that there were no general pattern between microclimate and Orthoptera assemblages in the studied years. Consequently the primary hypothesis, that there is correlation between the climatic variables and the community characteristics of Orthoptera assemblages, has not been proved for sure.

Table 6: Spearman rank correlations (r_s) between Temperature Gradient Indices and community characteristics of the Orthoptera assemblages in 1998 and 1999 (-: no significance, *: 0.05<p<0.1, **: p<0.05).

1998	$TGI1_{0.0m}$	$TGI1_{0.2m}$	$TGI1_{0.4m}$	$TGI2_{0.0m}$	$TGI2_{0.2m}$	$TGI2_{0.4m}$
Number of individuals	0.7500 *	-	-	0.8571 **	-	-
Balcanian-Illyrian elements	-	-	-	-	-0.7412 *	-0.7042 *
Balcanian elements	-	-	-	-	-0.7412 *	-0.7042 *
Thamnobionts elements	-	-0.7500 *	-	-	-0.7857 **	-

1999	TG/10.0m	TG/10.2m	TG/10.4m	TG/20.0m	TG/20.2m	TG/20.4m
Effective number of species	0.7857 **	-	-	0.8571 **	-	-
Shannon diversity	0.7857 **	-	-	0.8571 **	-	-
Evenness	0.6786 *	0.7143 *	-	0.7500 *	-	-
Sibirian-policentric elements	-	0.7143 *	0.7500 *	-	-	-
Sibirian elements	-	-	-	-0.6786 *	-	-
Geo-Chotobionts	-	0.7093 *	-	-	-	-
Proportion of Ensifera	-	0.6786 *	-	-	-	-

The connection between microclimate and Orthoptera assemblages was detected but without the identification of any general pattern. The fact that composition of the Orthoptera assemblages is influenced not only by the actual climatic condition can explain this controversy. The composition of the Orthoptera assemblages is particularly influenced by the precedent weather especially during the larval development of the species. Thus the deep understanding of this complex interaction needs further investigations.

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