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COMPARATIVE ANALYSIS OF STRUCTURAL CHARACTERISTICS OF GROUND BEETLES COMMUNITY (Carabidae: Coleoptera) ALONG AN URBAN-RURAL GRADIENT IN SKOPJE CITY AND ITS SURROUNDING

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ABSTRACT

Gorgievska C.A., Prelik D., Hristovski, S. & Georgiev B. (2009). Comparative analysis of structural characteristics of ground beetles community (Carabidae: Coleoptera) along an urban-rural gradient in Skopje city and its surrounding. Ekol. Zašt. Život. Sred. 12(1/2): 31-44.

Comparative analyzes of structural characteristics of ground beetles in three different localities (urban - U, suburban - S and rural - R) along the urban-rural gradient in Skopje city and its surrounding was followed.

The material was collected monthly, during one year period (07.2004 – 07.2005) by pitfall trapping along transect.

In total, 61 species, and 28 genera were registered. In total 3.03 ind.·trap^{-1} were registered, in R - 3.42 ind.·trap^{-1}, in S – 2.54 ind.·trap^{-1} and in U - 3.13 ind.·trap^{-1}. Dominant species were *Calathus melanocephalus* (Linnaeus, 1758)*, Calathus cinctus* (Motschulsky, 1850)*, Harpalus serripes* (Quensel, 1806) and *Amara aenea* (De Geer, 1774).

Structural features of ground beetles (Carabidae: Coleoptera) has been done trough examination of structural characteristics such as Index of richness – d; Index of diversity – H'; Index of homogeneity – $J_{(e)}$; Index of dominance - DI and Index of similarity - s, comparatively in three different localities.

There were similar oscillations of d and H' which had highest values during early summer period and lowest during February. Values of H' and $J_{(e)}$ were almost identical and positively correlated. DI was negatively correlated to the other indexes. Highest values were registered during February in R and May in S, while lowest during July in S. Index of similarity (s) was highest between urban and rural locality (66.67%) in winter period.

Key words: ground beetles, urban-rural gradient, structural indexes

АПСТРАКТ

Ѓоргиевска Ц.А., Прелиќ Д., Христовски, С. и Георгиев Б. (2009). Споредбена анализа на структурните одлики на тркачите (Carabidae: Coleoptera) по должина на урбано-рурален градиент во градот Скопје и неговата околина. Екол. Зашт. Живот. Сред. 12(1/2): 31-44.

Направена е споредбената анализа на структурните одлики на тркачите во трите различни локалитети (урбан-U, субурбан-S и рурален-R) по должина на урбано-рурален градиент во градот Скопје и неговата околина, преку одредување на структурните индекси: индекс на богатство – d; индекс на диверзитет – H'; индекс на хомогенитет – $J_{(e)}$; индекс на доминација - DI и индекс на сличност – s.

Материјалот е колекциониран месечно во текот на една година (07.2004 – 07.2005) со помош на ловни замки поставени по должина на трансект.

Во текот на истражувањето, регистрирано е присуство на 61 вид, кои припаѓаат на 28 родови. Во однос на квантитативниот состав, забележани се вкупно 3,03 инд.замка$^{-1}$, од кои 3,42 инд.замка$^{-1}$ во руралниот, 2,54 инд.замка$^{-1}$ во субурбаниот и 3,13 инд.замка$^{-1}$ во урбаниот локалитет. Со својата доминантност по должина на градиентот се издвојуваа родовите *Calathus, Harpalus* и *Amara*, како и видовите *Calathus melanocephalus, Calathus cinctus, Harpalus serripes* и *Amara aenea*.

Индексите на богатство – d и диверзитет – H' се со слични вредности, највисоки во текот на летото и најниски во текот на месец февруари. Индексот на хомогенитет – $J_{(e)}$ осцилира во потесни граници. Вредностите на диверзитетот и хомогенитетот се скоро идентични и правопропорционални. Индексот на доминација – DI е во негативна корелација со останатите индекси. Највисоки вредности се забележани во текот на февруари во руралниот и мај во субурбаниот локалитет, додека најниски во јули во субурбаниот локалитет. Индексот на сличност – s е највисок помеѓу урбаниот и руралниот локалитет (66.67%) во текот на зимскиот период.

Забележани се разлики во структурните одлики на тркачите помеѓу локалитетите, како резултат на различните еколошки услови по должината на градиентот.

Клучни зборови: тркачи, урбано-рурален градиент, структурни индекси

Introduction

Many studies were conducted as a part of the GLOBENET project (Global network for monitoring biodiversity changes across urban-rural landscapes) in the last decade where species composition and abundance of arthropods along an urban-rural gradient were analyzed. According to McDonell (1993), this gradient represents the differences of structural and functional components of ecosystems. Comparison of the obtained results gives opportunity for real evaluation of urban environment which is the reason in the bases of cenological investigation to involve the concept of "urban-rural gradients". The investigations along these gradients usually are made trough following the changes of structural characteristics of different animal groups, mainly Carabidae (Niemelä et al. 2000).

The area of the Skopje city, suffers significant changes of the animal and plant communities in the last decades as a result of intensive economical, sociological and demographic development. This was the main reason to conduct detailed ecological investigation of terrestrial macrofauna along an urban-rural gradient in Skopje and its surrounding, where as a model group was family Carabidae.

Biocenological structure of ground beetles (Carabidae, Coleoptera) is a parameter which can be used as a bioindicator of the changes of community structure along the urban-rural gradient (Stork 1990; Desender 1996; Luff 1996; Niemelä 1996; Dufrêne & Legendre 1997).

There are no literature data on spatial variation of the structural characteristics of ground beetles along an urban-rural gradient, which includes biotops with ruderal and meadow vegetation. According to Prelik (2002) the analyses of the structure of carabidocenosis were conducted in beech and oak forest ecosystems of the temperate region, in Mediterranean habitats of South France with different type of vegetation (David et al. 1999), in forest of *Pinus sylvestris* in the Netherlands (Berg et al. 1998) and in Canadian boreal forests (Paquin & Coderre 1997).

The purpose of the present study is to make a basic approach to the structural characteristics of the ground beetles community, as well as to analyze their qualitative and quantitative characteristics.

Area of investigation

The investigations were conducted in the central part of the city of Skopje and its surrounding. Climate-diagram of the city Skopje is presented on Fig. 1. Meteorological measurements were conducted by the Hydro-meteorological Institute from Skopje, located at the meteorological station Zajčev Rid, at an altitude of approximately 270 m. Climatic conditions were followed during 40 years (1951-1990).

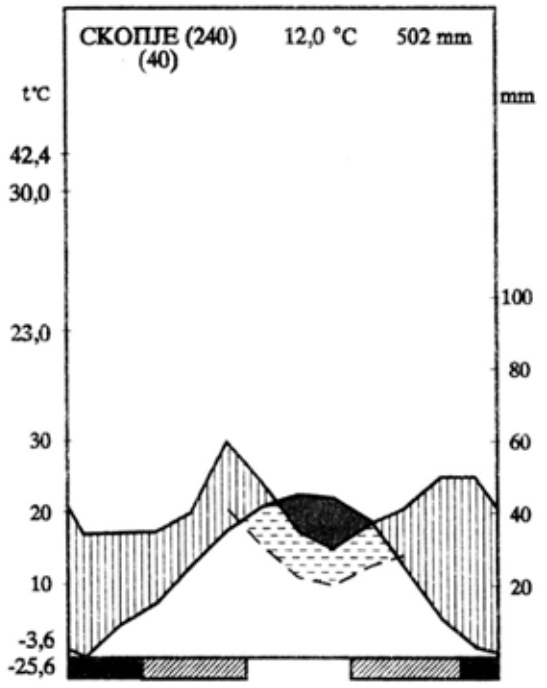

Fig. 1. Climadijagram for the investigation period of 40-years (1951 – 1990) in Skopje city (from Filipovski et al. 1996.)

Сл. 1. Климадијаграм за период од 40 години (1951-1990) во градот Скопје (Филиповски и сор. 1996)

Skopje city and its environment are characterized with temperate-cold winters and warm summers. The average annual temperature is 12.0 °C.

The absolute maximal monthly temperatures reach 42.4 °C (July). The absolute minimal month temperature is -25.6 °C (January). Maximal mean monthly temperature is 30.0 °C (August). The minimal mean-monthly temperature is -3.6 °C (January). During all year, with the exception of the summer period, days with absolute minimal temperature below zero, were registered, during January, February and December (Fig. 1.). The annual number of tropical days is 50, while the annual sum of the summer days is 123. Skopje city has 80 frosty days.

Skopje is characterized by relatively small amount of rains during the year (Fig. 1). The annual sum of precipitation is 502 mm, the lowest is in the warmest month of August (29,0 mm), and the highest is during May (60,8 mm). Compared by seasons, autumn is more rainy than spring. The annual relative air humidity is 69%. Arid period was registered during summer months. Semiarid period exist from the second half of May till the end of October. Generally, climate is temperate-warm according to temperature, and semi-arid according to humidity (Filipovski et al. 1996).

Geological composition is heterogenic, consisted mainly of clastic sediments, with domination of tertiary lake and sea sediments.

Characteristics of the investigated localities

A way to investigate the urbanization influence on the environment is to analyze the structure and function of the ecosystem along an urban-rural gradient (McDonnell and Pickett 1990). Urban areas are densely populated, developed and highly urbanized, surrounded with less urbanized areas (Dickinson 1966). According to Shochat et al. (2003), rural areas are residential zones which are not included in the urbanizing plan; suburban areas are those which surround urban parts of the city, with relatively small number of constructing objects (2,5-10 ha) and small amount of green surface (20-50 %); urban areas are the one which are dominated with constructing objects (10 constructing objects /ha). According to Magura et al. (2005), the criteria for urban, suburban and rural areas are the percent of the constructing objects. Namely, this percent in the urban area is 60%, in suburban approximately 30% and in rural area 0%.

Based on the cartographic data (Markovski and Gorin, pers. comm.) for the position of the investigated area, and the appropriate phytocenological analyzes (Kostadinovski, pers. comm.), gradient was placed starting from:

1. Urban locality (U): highly disturbed urban area - the area that is nearest to the swimming poll ”Карпош“ and the Military Hospital. The same is placed in the central part of the city, at the right site of the River Vardar, at the altitude of 252 m, covering the surface area of 1,38 hectares. The frequency of traffic is very intensive, and near by is a constructing object. Also this is part of the city where air pollution is very high. Trees are absent in this locality. Phytocenosis belong to the class of Chenopodietea Br.-Bl. 1952, order Chenopodietalia Br.-Bl. (1931) 1936, alliance Hordeion Br.-Bl. (1931) 1947, as well as parts of other alliances and orders of the same class and parts of communities of grazed habitats.

2. Suburban locality (S). Less disturbed suburban area - the area which almost identically reflects the characteristics of the suburb zone, meaning part which is at appropriate distance from the city center; where urbanization and air pollution are less intensive. The same is named as suburb locality (S) and it is placed near the municipality Madžari and grocery market**.** This locality is placed at the left site of the River Vardar, at the 234,6 m altitude with surface area of 0,788 hectares. The trees are rare, only at the periphery of the biotope. The transects are placed at the quite diverse vegetation surface, with fitocenosis which belong to few classes of ruderal vegetation, such as: Polygono arenastri-Poetea annuae Rivas-Martinez 1975 corr. Rivas-Martinez et al. 1991, Stellarietea mediae Tx. et al. 51, Artemisietea Lohm. et al. 51 et Galio-Urticetea Passarge et Kopecky 69 (Матвејева, 1982; Čarni et al., 1997, 2002).

3. Rural locality (R). Undisturbed rural area - rural locality (R) is placed nearest to the village Mralino and the road Skopje-Veles, at about 24 km distance from the Skopje city.

This locality is placed at the left site of the River Vardar, at the altitude of 227 m and with surface of 5,1 hectares. Trees are rare and surround the biotope. Although there is some transformation to sinantropic vegetation, the vegetation in this locality belongs to the class of meadow community Molinio-Arrhenatheretea R. Tx. 1937 em. R. Tx. 1970, order *Arrhenatheretalia* R. Tx. 1937, alliance *Cynosurion* R. Tx. 1947, Communities are developed on habitat which is used for grazing, which prevents the development of this vegetation to a typical meadow community.

Along the gradient (in all three localities), similar phytocenological composition was noticed (especially between suburban and urban locality), represented with ruderal vegetation.

Material and methods

The investigation was conducted monthly (July 2004-July 2005), by using pitfall traps. Pitfall traps is the usual method for sampling epigean insects. This method is not the most appropriate for direct estimation of absolute true density, but it is useful to compare population size and community structure in space and time (Dent & Walton 1997;

Duelli et al. 1999; Perner & Schueler 2004; Grez, et al. 2004).

Within each locality, three transects were randomly placed, each transect line was approximately 50–100 m apart, and at each 10 pitfall traps were placed, 10 m apart. In total, there were three localities, 9 transects and 90 traps. Each pitfall trap consisted of plastic cup, which was placed flush with the surface of the soil. The pitfall traps were half filled (200 ml) with formalin - vinegar solution, in 1:7 ratio, which acted as killing and preserving agent of the catch. Plastic roofs were placed at each trap, a couple of centimeters above, to prevent dilution of preservative from the rain water.

Collected beetles were analyzed ecologically and taxonomically, classified to species.

Structural characteristics of the ground beetles community were determined by analyzing structural indexes: index of richness – d; Schaennon-Wiener's index of diversity – H'; index of homogeneity – $J_{(e)}$; index of dominance - DI and index of similarity – s:

- **Index of species richness - d** (according to Margalef (1958)):

$$d = \frac{n-1}{\ln N}$$

where n is the number of present species, **N** is the total number of individuals

- **Index of diversity** (presence) of different species - **H'** (according to Schaennon-Wiener, from Glowacinsky (1975)):

$$H' = \sum_{i=1}^{s} p_i \ln p_i \qquad p_i = \frac{n_i}{N}$$

where $\mathbf{n_i}$ is the number of individuals from i - species, and **N** is the total number of individuals

- **Index of homogeneity** (equal distribution and presence of different species with individuals) - $\mathbf{J_{(e)}}$ (according to Pielou (1966)) :

$$J_{(e)} = \frac{H'}{\ln S}$$

where **H'** is Shannon's index of diversity.

- **Index of dominance - DI** (according to Karr (1971)):

$$DI = \frac{Y_1 + Y_2}{Y} * 100$$

where $\mathbf{Y_1}$ is the abundance of the first dominant species, $\mathbf{Y_2}$ is the abundance of the second dominant species, and **Y** is the total abundance of the community.

- **Index of similarity (s)** – of the species composition in different localities / months (according to Marczewski and Steinhaus (1959)):

$$s = \frac{W}{a + b - W} * 100$$

where **W** is the number of common species, **a** is the total number of species in one locality / month, **b** is the total number of species in the other locality / month.

Results

d, **H'**, **J(e)** and **DI**, in urban locality, were followed trough the investigation period (Fig.2). Except for the index of dominance, the other indexes showed similar values, higher during spring and summer and lower recorded in autumn and winter period. **DI** had inverse relationship: highest values in autumn-winter period, with maximal values noticed in December (92,95%). During the same month, indexes of richness – d (1,17) and diversity – H' (0,98), reached minimal values. Dominant species were *Calathus cinctus* (Motschulsky, 1850), *Calathus melanocephalus* (Linnaeus, 1758), *Amara aenea* (De Geer, 1774) and *Harpalus serripes* (Quensel, 1806) trough all the year. *Calathus melanocephalus* and *Calathus cinctus* were dominant species during autumn and winter months, *Amara aenea* during spring period, while *Harpalus serripes* was dominant species in summer (Tab. 4, 5, 6 and 7).

d reached maximal values in May 2005 (3,56) and June (4,06). Values of diversity – H' and homogeneity – J(e) were similar during all year, higher in spring-summer period, while during autumn and winter their decrease was noticed.

J(e) had relatively low values and ranged between 0.47 (in February 2005) and 0.85 (March 2005), with minor oscillations during the rest of the year.

H' had larger variations during the year, with maximal values reached in summer, especially in June 2005 (2,16).

Variations of structural indexes (d;, H', J(e), DI) during the investigation period in suburb locality are shown on Fig.3. **d** and H' had similar values through all year. Their values were high during all year, except for the winter period when their decrease was noticed. **H'** reached maximal values in summer (July 2004 – 1,97), and minimal values in May (0,63). $\mathbf{J_{(e)}}$ - showed larger variations in contrast to urban locality, but in relatively narrower range, from 0.52 (November 2004) to 0.91 (May 2005).

Once more, all the indexes except for DI showed similar values: higher during spring and summer and lower in autumn and winter period. Except for the summer period, **DI** had higher values trough all year, with maximum reached in May (100%) and December (91.30%). d (0,78 in December) and H' (0,63 in May) reached minimal values during this months. Minimal values of DI were noticed in July 2005 (15,38%). Dominant species were *Calathus melanocephalus, Calathus cinctus* and *Harpalus*

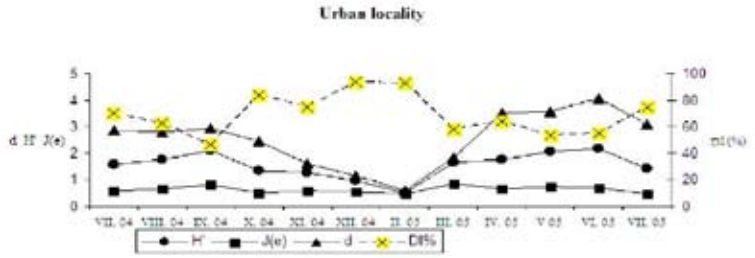

Fig.2. Seasonal variation of the structural characteristics (d, H', $J_{(e)}$, DI) of the carabidocenosis in urban locality
Сл.2. Сезонски промени на структурните карактеристики (d, H', $J_{(e)}$, DI) на карабидоценозата во урбаниот локалитет

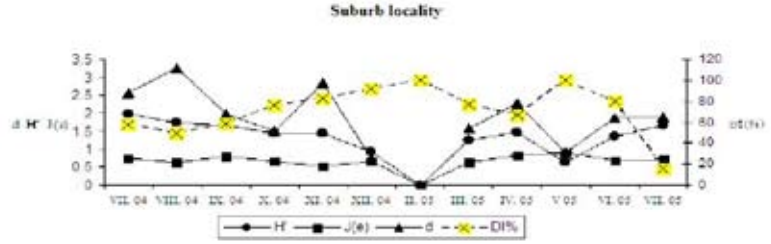

Fig. 3. Seasonal variation of structural characteristics (d, H', $J_{(e)}$, DI) of carabidocenosis in suburb locality
Сл. 3. Сезонски промени на структурните карактеристики (d, H', $J_{(e)}$, DI) на карабидоценозата во субурбаниот локалитет

serripes, while *Amara aenea* was recendent species during all year. *Calathus cinctus* and *Calathus melanocephalus* were dominant species in greatest part of the year, especially during autumn, winter and spring months. *Amara aenea* and *Harpalus dimidiatus* reached highest values for dominance in April 2005, although they were recendent during the resto of the year. *Harpalus rubripes* was dominant in September and *Harpalus serripes* was dominant during summer months (Tab. 4., 5., 6., 7.).

Index of richness – d despite the other indexes showed somewhat higher values, but also and more expressed variations during all year. Maximal values were reached in August (3,26) and minimal in December (0,78).

d, H' and J(e) showed similar values in rural locality - higher in spring and summer period, and lower in autumn and winter period (Fig.4.). **DI** had inverse relationship with other indexes and reached highest values in winter. Maximal values were noticed in September (86.06%). J(e) and H' reached minimal values in this month (0.36 and 0.84, respectively). Minimal value of dominance was registered in July 2004 (40.9%). *Calathus melanocephalus, Calathus fuscipes* and *Amara aenea* stand out by their dominance through whole year. *Calathus cinctus* was subdominant, while *Harpalus serripes* and *Harpalus dimidiatus* were subrecendent. *Harpalus dimidiatus* was dominant species during the summer, *Calathus* species (mainly *Calathus melanocephalus* and *Calathus fuscipes*) were dominant in autumn period. *Trechus quadristriatus* was dominant in winter months while *Amara aenea* reached highest abundance and dominance during the spring (Tab. 4., 5., 6., 7.).

d reached highest values in July 2004 (3.57) and April 2005 (3.47), while minimal were noticed in December (0.77) and February (0.28). Again, the annual changes in H' and J(e) showed similar pattern to d. **J(e)** in this locality reached relatively high values during winter period and showed minor oscillations during the investigated year, with equal presence of different species.

H' reached maximal values during summer period with peak in July 2005 (2.27), and minimal in February (0.62) and September (0.84). There were smaller variations with the exception of September and February.

Average values of indexes (d, H',J(e) and DI) along an urban-rural gradient in the city of Skopje are shown on Fig. 5. Compared by localities, d had highest value in U (2.53). J(e) had similar values in all three localities (0.64-0.71). Also, H' shows low variations. All of these indexes had lowest values in S.

Values of DI were determined by the dominance of separate species. *Calathus melanocephalus* was equally dominant in all three localities. *Calathus cinctus* and *Harpalus serripes* were dominant in S, besides *Calathus melanocephalus*, *Amara aenea* was dominant in U. The lowest values were no-

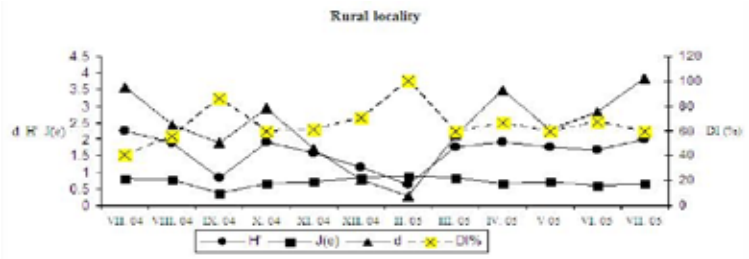

Fig. 4. Seasonal variation of structural characteristics (d, H', $J_{(e)}$, DI) of carabidocenosis in rural locality
Сл. 4. Сезонски промени на структурните карактеристики (d, H', $J_{(e)}$, DI) на карабидоценозата во руралниот локалитет

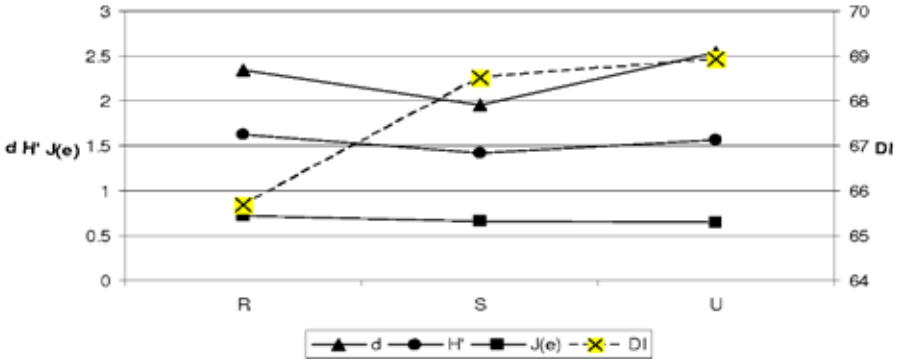

Fig. 5. Spatial variation of the structural characteristics (d, H', $J_{(e)}$, DI) of the carabidocenosis along an urban-rural gradient in Skopje city and its surrounding
Сл. 5. Сезонски промени на структурните карактеристики (d, H', $J_{(e)}$, DI) на карабидоценозата по должина на урбано-рурален градиент во градот Скопје и неговата околина

ticed in R (65.68%). which are due to the dominance of *Calathus melanocephalus*, *Amara aenea* and *Calathus fuscipes*.

S was made with aim to evaluate the percent of similarity in community composition between seasons in three different localities along the gradient. Tab. 1. shows the matrices of similarity and points up that similarity of the community composition in rural locality was highest in autumn-spring period. In suburb locality this index was highest dur-

Tab. 1. Similarity of community structure of carabidocenosis along an urban-rural gradient during the investigated period (07.2004 – 07. 2005)
Таб. 1. Сличност во составот на карабидоценозите по должина на урбано-руралниот градиент во текот на истражуваниот период (07.2004 – 07. 2005)

Spring / Пролет	Summer/Лето	Autumn/Есен	Winter/Зима	R
100.00	39.40	43.00	8.00	**Spring/Пролет**
	100.00	38.00	3.00	**Summer/Лето**
		100.00	20.00	**Autumn/Есен**
			100.00	**Winter/Зима**

Spring/Пролет	Summer/Лето	Autumn/Есен	Winter/Зима	S
100.00	21.00	30.00	15.00	**Spring/Пролет**
	100.00	44.80	12.50	**Summer/Лето**
		100.00	21.00	**Autumn/Есен**
			100.00	**Winter/Зима**

Spring/Пролет	Summer/Лето	Autumn/Есен	Winter/Зима	U
100.00	**58.00**	42.40	17.20	**Spring/Пролет**
	100.00	42.80	15.60	**Summer/Лето**
		100.00	35.00	**Autumn/Есен**
			100.00	**Winter/Зима**

ing autumn-summer period, while in urban locality highest values of this index were registered in summer-spring period. In all three localities the similarity of the community composition was lowest during winter-summer period.

Discussion

Along the gradient, **index of richness (d**) showed similar values during all year in suburb and rural locality, while it was quite different in urban locality, especially during the spring period. The lowest value was noticed in suburb locality (1.95), while the highest in urban locality (2.53). Compared by seasons, this index reached higher values in spring-summer and autumn part of the year, which coincides with the higher total abundance of carabids. Ground beetles showed higher activity during warmer period of the year, and they migrate in lower layers of soil searching for shelter and better conditions during the winter because of the unfavorable conditions (Vidinčeva 1995).

In rural locality as a result of rich qualitative composition, there were high values of index of richness during July 2004 (in total 17 species), October (16 species), April (18 species) and July 2005 (20 species). **In suburb locality**, high values were recorded in August (15 species) and November (16 species), while in **urban locality** high values of this index were recorded in May (16 species) and June (20 species).

Index of diversity (H') highest values reached in rural and lowest in suburb locality. In all three localities values were higher during autumn and spring-summer period as a result of the life cycles of ground beetles which are mainly spring breeders. According to Prelik & Georgievska (1999) the appearance of new groups in spring and favorable microclimatic conditions enlarges diversity as a whole. During the winter, the diversity was lower because of the limited food resources. Also, lower value of diversity in winter months along the gradient, points up the existence of species which reproduce in spring, so called "summer insects". These beetles spend the summer period as larvae and in autumn give new generation which hibernates as an adult stage in winter. Index of diversity is a function of the number of different species (index of richness) and their equal distribution in the community (index of homogeneity) (Prelik 2002).

Lower value of diversity (0,84) **in rural locality** during September was a result of high value of index of dominance (86.05%), due to the high abundance of *Calathus fuscipes* (3.33 ind.·trap^{-1}). High values reached in July 2004 (d=3.57; H'=2.27) and July 2005 (d=3.81; H'=2.01) when 17 and 20 species were registered, and without major oscillations during the year, except for September (d=1.87; H'=0.84) and February (d=0,28; H'=0,62) when 10 species (DI=86.06%) and 2 species (DI=100%) were registered, respectively. **In suburb locality** this index was without significant oscillations and it reached higher values in July 2004 (14 species) and 2005 (10 species), while lower value except in winter period, was also noticed in May, when only 2 species were registered and the index of dominance was 100%. Lower value of H' during May in this locality was a result of lower value of richness. **In urban locality** in September, June and July 2005 highest values were reached, while the lowest were noticed in winter period. In September higher value was reached when despite the lower abundance, higher number of species increases diversity. Smaller value was noticed in July 2005 because of the dominance of *Harpalus serripes* (4.83 ind.·trap^{-1}).

Similar values of **index of homogeneity ($J_{(e)}$)** were noticed in U and SU. Analyzed by months, values of d and H' were higher and the community was more homogenous during autumn and spring-summer period. Minor changes of their values during the year were due to local migrations of ground beetles caused by the changes of the environment (Prelik 2002). According to the same author, different growing cycles of carabids determine change of their composition and diversity. Decrease of this index was noticed during February, which was expected because the diversity is equally proportional to richness, and during this month there were few species registered, which points to the existence of unstable community. During winter months, there were only few species (*Calathus* spp.*, Amara aenea, Harpalus distinguendus, Trechus quadristriatus, Lebia cyanocephala, Brachinus explodens, Pterostichus niger, Laemostenus punctatus, Amara eurynota, Zabrus tenebrioides, Harpalus dimidiatus, Harpalus rubripes, Parophonus maculicornis, Microlestes minutulus, Syntomus pallipes*), which also were dominant and contribute do the decrease of $J_{(e)}$. Therefore, we can say that these species were autumn breeders, or "winter insects".

The highest value reached **in rural locality** and point up the existence of homogenous community. Namely, the existence of large number of ecological niche, suitable pedological composition and microclimate in this habitat create suitable conditions for colonization of macropedofauna. So, as species richness and diversity are higher so the community is more stable and homogenous. Also, in this locality there were not any major oscillations of homogeneity, which is due to the equal presence of different species and small changes of their abundance during the year. Followed by months, the lowest value was registered in September 2004 which was due to the presence of the species *Calathus fuscipes* who reached abundance of 3.33 ind.·trap^{-1}. Higher value of homogeneity during winter period was proba-

bly as a result od the presence of the winter species, mostly of the genus *Calathus* (*C. melanocephalus, C. cinctus* and *C. fuscipes*) which enlarge the diversity and the stability of the community with their abundance. In **suburb locality** high value of homogeneity was noticed in May 2005 because of the presence of only two species *Calathus cinctus* (0.06 ind.·trap^{-1}) and *Poecilus cupreus* (0.03 ind.·trap^{-1}), although with small abundance. **In urban locality** index of homogeneity was highest during September when 12 species were registered and there was relatively low index of dominance (46.51%).

Index of similarity (s) showed high faunistic similarity during the year, with the exception of the winter period (Tab. 1.).

Generally during the year, structural characteristics were higher in autumn and spring-summer period, with smaller oscillations, due to their life cycles and seasonal variations of the climate, which is characteristic of the areas of temperate region. Equal presence of species and the existence of similar composition in different months of the year were registered. It stresses the stability and homogeneity of the community, which does not suffer significant changes during the year (Vidinčeva, 1995). Along the gradient, structural indexes were higher in rural locality which points up the existence of relatively suitable physico-chemical characteristics and mechanical composition of soil, appropriate hydrotermical conditions and phytocenological composition.

Conclusions

Along the gradient, zoocenological evaluation of the carabidocenosis structure showed that indexes were higher in rural locality which points up the existence of relatively suitable hydrotermical, physico-chemical and mechanical conditions of the soil as well as appropriate phytocenological composition.

During the year, structural indexes d; H'; s; $J_{(e)}$ were higher during autumn and spring-summer period, due to the life cycle of ground beetles and seasonal variation of the climate. This stresses the existence of community which is homogenous and relatively stable and does not have and significant changes during the year.

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СПОРЕДБЕНА АНАЛИЗА НА СТРУКТУРНИТЕ ОДЛИКИ НА ТРКАЧИТЕ (Carabidae: Coleoptera) ПО ДОЛЖИНА НА УРБАНО-РУРАЛЕН ГРАДИЕНТ ВО ГРАДОТ СКОПЈЕ И НЕГОВАТА ОКОЛИНА

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Резиме

Во текот на едногодишното истражување во периодот помеѓу 07.2004 – 07.2005, беше направена споредбена анализа на структурните одлики на тркачите во трите различни локалитети (урбан-U, субурбан-S и рурален-R) по должина на урбано-рурален градиент во градот Скопје и неговата околина, преку одредување на структурните индекси: индекс на богатство – d; индекс на диверзитет – H'; индекс на хомогенитет – $J_{(e)}$; индекс на доминација - DI и индекс на сличност – s.

При тоа беше регистрирано присуство на 61 вид (28 родови). Во однос на квантитативниот состав, беа забележани вкупно 3,03 инд.замка$^{-1}$, од кои 3,42 инд.замка$^{-1}$ во руралниот, 2,54 инд.замка$^{-1}$ во субурбаниот и 3,13 инд.замка$^{-1}$ во урбаниот локалитет. Со својата доминантност по должина на градиентот се издвојуваа родовите *Calathus, Harpalus* и *Amara*, како и видовите *Calathus melanocephalus, Calathus cinctus, Harpalus serripes* и *Amara aenea*.

Беа забележани разлики во структурните одлики на тркачите помеѓу локалитетите, како резултат на различните еколошки услови по должината на градиентот.

Tab. 2. Relative abundance and dominance of different genus's of family Carabidae along an urban-rural gradient in city of Skopje and its surrounding
Таб. 2. Релативна абундантност и процентуално учество на одделните родови од фамилијата Carabidae по должина на урбано-руралниот градиент во Скопската Котлина

Родови	R				S				U				цел градиент			
	број	инд.замка$^{-1}$	доминантност		број	инд.замка$^{-1}$	доминантност		број	инд.замка$^{-1}$	доминантност		број	инд.замка$^{-1}$	доминантност	
Calathus	475	1.32	38.6	**D**	477	1.33	52.2	**D**	421	1.17	37.4	**D**	1373	1.27	42.0	**D**
Harpalus	317	0.88	25.7	**D**	308	0.86	33.7	**D**	382	1.06	33.9	**D**	1007	0.93	30.8	**D**
Amara	188	0.52	15.3	**D**	33	0.09	3.6	**R**	147	0.41	13.0	**D**	368	0.34	11.2	**D**
Trechus	98	0.27	8.0	**SD**	12	0.03	1.3	**R**	8	0.02	0.7	**SR**	118	0.11	3.6	**R**
Ophonus	29	0.08	2.4	**R**	14	0.04	1.5	**R**	71	0.20	6.3	**SD**	114	0.11	3.5	**R**
Brachinus	40	0.11	3.2	**R**	8	0.02	0.9	**SR**	19	0.05	1.7	**R**	67	0.06	2.0	**R**
Parophonus	22	0.06	1.8	**R**	33	0.09	3.6	**R**	11	0.03	1.0	**R**	66	0.06	2.0	**R**
Syntomus	2	0.01	0.2	**SR**	9	0.03	1.0	**R**	27	0.08	2.4	**R**	38	0.04	1.2	**R**
Poecilus	30	0.08	2.4	**R**	1	0.00	0.1	**SR**	0	0.00	0.0		31	0.03	0.9	**SR**
Dixus	2	0.01	0.2	**SR**	1	0.00	0.1	**SR**	20	0.06	1.8	**R**	23	0.02	0.7	**SR**
Chlaenius	11	0.03	0.9	**SR**	0	0.00	0.0		0	0.00	0.0		11	0.01	0.3	**SR**
Microlestes	5	0.01	0.4	**SR**	1	0.00	0.1	**SR**	5	0.01	0.4	**SR**	11	0.01	0.3	**SR**
Pangus	0	0.00	0.0		0	0.00	0.0		7	0.02	0.6	**SR**	7	0.01	0.2	**SR**
Carabus	0	0.00	0.0		7	0.02	0.8	**SR**	0	0.00	0.0		7	0.01	0.2	**SR**
Zabrus	0	0.00	0.0		4	0.01	0.4	**SR**	2	0.01	0.2	**SR**	6	0.01	0.2	**SR**
Masoreus	0	0.00	0.0		1	0.00	0.1	**SR**	3	0.01	0.3	**SR**	4	0.00	0.1	**SR**
Pterostichus	4	0.01	0.3	**SR**	0	0.00	0.0		0	0.00	0.0		4	0.00	0.1	**SR**
Laemostenus	0	0.00	0.0		3	0.01	0.3	**SR**	0	0.00	0.0		3	0.00	0.1	**SR**
Licinus	0	0.00	0.0		0	0.00	0.0		3	0.01	0.3	**SR**	3	0.00	0.1	**SR**
Acupalpus	1	0.00	0.1	**SR**	1	0.00	0.1	**SR**	0	0.00	0.0		2	0.00	0.1	**SR**
Stenolophus	2	0.01	0.2	**SR**	0	0.00	0.0		0	0.00	0.0		2	0.00	0.1	**SR**
Anchomenus	1	0.00	0.1	**SR**	0	0.00	0.0		0	0.00	0.0		1	0.00	0.0	**SR**
Cymindis	0	0.00	0.0		0	0.00	0.0		1	0.00	0.1	**SR**	1	0.00	0.0	**SR**
Bembidion	1	0.00	0.1	**SR**	0	0.00	0.0		0	0.00	0.0	**SR**	1	0.00	0.0	**SR**
Lebia	1	0.00	0.1	**SR**	0	0.00	0.0		0	0.00	0.0		1	0.00	0.0	**SR**
Nebria	0	0.00	0.0		0	0.00	0.0		1	0.00	0.1	**SR**	1	0.00	0.0	**SR**
Gynandromorphus	0	0.00	0.0		1	0.00	0.1	**SR**	0	0.00	0.0		1	0.00	0.0	**SR**
Polystichus	1	0.00	0.1	**SR**	0	0.00	0.0		0	0.00	0.0		1	0.00	0.0	**SR**
Вкупно	1230	3.42			914	2.54			1128	3.13			3272	3.03		

Tab. 3. Relative abundance and dominance of different species of family Carabidae along an urban-rural gradient in city of Skopje and its surrounding
Таб. 3. Релативна абундантност и процентуално учество на одделните видови од фамилијата Carabidae по должина на урбано-руралниот градиент во Скопската Котлина

Видови	R				S				U				цел градиент		
	број	инд.замка$^{-1}$	доминантност		број	инд.замка$^{-1}$	доминантност		број	инд.замка$^{-1}$	доминантност		инд.замка$^{-1}$	доминантност	
N. brevicollis	0	0.00	0.0		0	0.00	0.0		1	0.00	0.1	SR	0.00	0.0	SR
C. coriaceus	0	0.00	0.0		7	0.02	0.8	SR	0	0.00	0.0		0.01	0.2	SR
B. explodens	40	0.11	3.2	R	8	0.02	0.9	SR	19	0.05	1.7	R	0.06	2.0	R
Bembidion sp.	1	0.00	0.1	SR	0	0.00	0.0		0	0.00	0.0		0.00	0.0	SR
T. quadristriatus	98	0.27	8.0	SD	12	0.03	1.3	R	8	0.02	0.7	SR	0.11	3.6	R
C. decipiens	11	0.03	0.9	SR	0	0.00	0.0		0	0.00	0.0		0.01	0.3	SR
M. wetterhalli	0	0.00	0.0		1	0.00	0.1	SR	3	0.01	0.3	SR	0.00	0.1	SR
G. etruscus	0	0.00	0.0		1	0.00	0.1	SR	0	0.00	0.0		0.00	0.0	SR
D. clypeatus	1	0.00	0.1	SR	0	0.00	0.0		10	0.03	0.9	SR	0.01	0.3	SR
D. eremita	1	0.00	0.1	SR	1	0.00	0.1	SR	9	0.03	0.8	SR	0.01	0.3	SR
D. obscurus	0	0.00	0.0		0	0.00	0.0		1	0.00	0.1	SR	0.00	0.0	SR
H. albanicus	6	0.02	0.5	SR	0	0.00	0.0		0	0.00	0.0		0.01	0.2	SR
H. anxius	8	0.02	0.6	SR	16	0.04	1.7	R	7	0.02	0.6	SR	0.03	0.9	SR
H. dimidiatus	215	0.60	17.5	D	34	0.09	3.7	R	2	0.01	0.2	SR	0.23	7.7	SD
H. distinguendus	28	0.08	2.3	R	16	0.04	1.7	R	4	0.01	0.4	SR	0.04	1.5	R
H. picipennis	4	0.01	0.3	SR	0	0.00	0.0		2	0.01	0.2	SR	0.01	0.2	SR
H. pumilus	1	0.00	0.1	SR	0	0.00	0.0		12	0.03	1.1	R	0.01	0.4	SR
H. rubripes	10	0.03	0.8	SR	62	0.17	6.8	SD	9	0.03	0.8	SR	0.08	2.5	R
H. serripes	10	0.03	0.8	SR	170	0.47	18.6	D	324	0.90	28.8	D	0.47	15.4	D
H. subcilindricus	4	0.01	0.3	SR	7	0.02	0.8	SR	1	0.00	0.1	SR	0.01	0.4	SR
H. tardus	0	0.00	0.0		2	0.01	0.2	SR	5	0.01	0.4	SR	0.01	0.2	SR
H. triseriatus	1	0.00	0.1	SR	0	0.00	0.0		0	0.00	0.0		0.00	0.0	SR
H. rufipes	30	0.08	2.4	R	1	0.00	0.1	SR	16	0.04	1.4	R	0.04	1.4	R
O. azureus	17	0.05	1.4	R	10	0.03	1.1	R	6	0.02	0.5	SR	0.03	1.0	R
O. cribricollis	12	0.03	1.0	R	4	0.01	0.4	SR	64	0.18	5.7	SD	0.07	2.4	R
O. sabulicola	0	0.00	0.0		0	0.00	0.0		1	0.00	0.1	SR	0.00	0.0	SR
P. scaritides	0	0.00	0.0		0	0.00	0.0		7	0.02	0.6	SR	0.01	0.2	SR
P. hirsutulus	0	0.00	0.0		27	0.08	3.0	R	0	0.00	0.0		0.03	0.8	SR
P. dejeani	2	0.01	0.2	SR	1	0.00	0.1	SR	2	0.01	0.2	SR	0.00	0.2	SR
P. maculicornis	18	0.05	1.5	R	5	0.01	0.5	SR	6	0.02	0.5	SR	0.03	0.9	SR
P. complanatus	0	0.00	0.0		0	0.00	0.0		3	0.01	0.3	SR	0.00	0.1	SR
P. mendax	2	0.01	0.2	SR	0	0.00	0.0		0	0.00	0.0		0.00	0.1	SR

Видови	R				S				U				цел градиент		
	број	инд.замка$^{-1}$	доминантност		број	инд.замка$^{-1}$	доминантност		број	инд.замка$^{-1}$	доминантност		инд.замка$^{-1}$	доминантност	
A. meridianus	0	0.00	0.0		1	0.00	0.1	**SR**	0	0.00	0.0		0.00	0.0	**SR**
A. interstitialis	1	0.00	0.1	**SR**	0	0.00	0.0		0	0.00	0.0		0.00	0.0	**SR**
S. mixtus	2	0.01	0.2	**SR**	0	0.00	0.0		0	0.00	0.0		0.00	0.1	**SR**
C. axillaris	0	0.00	0.0		0	0.00	0.0		1	0.00	0.1	**SR**	0.00	0.0	**SR**
M. fulvibasis	3	0.01	0.2	**SR**	0	0.00	0.0		1	0.00	0.1	**SR**	0.00	0.1	**SR**
M. maurus	2	0.01	0.2	**SR**	0	0.00	0.0		3	0.01	0.3	**SR**	0.00	0.2	**SR**
M. minutulus	0	0.00	0.0		1	0.00	0.1	**SR**	1	0.00	0.1	**SR**	0.00	0.1	**SR**
L. cyanocephala	1	0.00	0.1	**SR**	0	0.00	0.0		0	0.00	0.0		0.00	0.0	**SR**
S. obscuroguttatus	2	0.01	0.2	**SR**	1	0.00	0.1	**SR**	19	0.05	1.7	**R**	0.02	0.7	**SR**
S. pallipes	0	0.00	0.0		8	0.02	0.9	**SR**	8	0.02	0.7	**SR**	0.01	0.5	**SR**
L. silphoides	0	0.00	0.0		0	0.00	0.0		3	0.01	0.3	**SR**	0.00	0.1	**SR**
A. dorsalis	1	0.00	0.1	**SR**	0	0.00	0.0		0	0.00	0.0		0.00	0.0	**SR**
P. anatolicus	15	0.04	1.2	**R**	0	0.00	0.0		0	0.00	0.0		0.01	0.5	**SR**
P. cupreus	15	0.04	1.2	**R**	1	0.00	0.1	**SR**	0	0.00	0.0		0.01	0.5	**SR**
P. macer	2	0.01	0.2	**SR**	0	0.00	0.0		0	0.00	0.0		0.00	0.1	**SR**
P. melanarius	1	0.00	0.1	**SR**	0	0.00	0.0		0	0.00	0.0		0.00	0.0	**SR**
P. niger	1	0.00	0.1	**SR**	0	0.00	0.0		0	0.00	0.0		0.00	0.0	**SR**
C. fuscipes	248	0.69	20.1	**D**	24	0.07	2.6	**R**	40	0.11	3.5	**R**	0.29	9.5	**SD**
C. ambiquus	8	0.02	0.6	**SR**	19	0.05	2.1	**R**	16	0.04	1.4	**R**	0.04	1.3	**R**
C. cinctus	73	0.20	5.9	**SD**	243	0.68	26.6	**D**	198	0.55	17.6	**D**	0.48	15.7	**D**
C. melanocephalus	146	0.41	11.9	**D**	191	0.53	20.9	**D**	167	0.46	14.8	**D**	0.47	15.4	**D**
L. punctatus	0	0.00	0.0		3	0.01	0.3	**SR**	0	0.00	0.0		0.00	0.1	**SR**
A. aenea	186	0.52	15.1	**D**	30	0.08	3.3	**R**	130	0.36	11.5	**D**	0.32	10.6	**D**
A. anthobia	2	0.01	0.2	**SR**	0	0.00	0.0		2	0.01	0.2	**SR**	0.00	0.1	**SR**
A. eurynota	0	0.00	0.0		2	0.01	0.2	**SR**	9	0.03	0.8	**SR**	0.01	0.3	**SR**
A. lucida	0	0.00	0.0		0	0.00	0.0		6	0.02	0.5	**SR**	0.01	0.2	**SR**
A. ingenua	0	0.00	0.0		1	0.00	0.1	**SR**	0	0.00	0.0		0.00	0.0	**SR**
Z.tenebrionides	0	0.00	0.0		4	0.01	0.4	**SR**	2	0.01	0.2	**SR**	0.01	0.2	**SR**
P. connexus	1	0.00	0.1	**SR**	0	0.00	0.0		0	0.00	0.0		0.00	0.0	**SR**
	1230	**3.42**			**914**	**2.54**			**1128**	**3.13**			**3.03**		

Tab. 4. Dominance of species *Calathus cinctus* in three different localities, during the investigated period
Таб. 4. Процентуално учество на видот *Calathus cinctus* во трите различни локалитети, во текот на истражуваниот период

месец	*Calathus cinctus*					
	R		S		U	
	доминантност		доминантност		доминантност	
07. 2004	0.00		1.24	R	3.04	R
08. 2004	0.00		0.00		0.46	SR
09. 2004	0.00		2.85	R	3.04	R
10. 2004	39.83	D	33.79	D	33.43	D
11. 2004	23.24	D	39.60	D	22.80	D
12. 2004	17.84	D	11.14	D	18.24	D
02. 2005	14.94	D	0.00		11.55	D
03. 2005	4.15	R	10.64	D	4.56	R
04. 2005	0.00		0.00		2.43	R
05. 2005	0.00		0.74	SR	0.00	
06. 2005	0.00		0.00		0.00	
07. 2005	0.00		0.00		0.46	SR

Tab. 5. Dominance of species *Calathus melanocephalus* in three different localities, during the investigated period
Таб. 5. Процентуално учество на видот *Calathus melanocephalus* во трите различни локалитети, во текот на истражуваниот период

месец	*Calathus cinctus*					
	R		S		U	
	доминантност		доминантност		доминантност	
07. 2004	0.00		16.22	D	4.68	R
08. 2004	0.00		0.00		0.00	
09. 2004	3.30	R	3.62	R	7.75	SD
10. 2004	54.85	D	36.69	D	63.60	D
11. 2004	32.99	D	35.59	D	5.95	SD
12. 2004	8.87	SD	7.87	SD	18.02	D
02. 2005	0.00		0.00		0.00	
03. 2005	0.00		0.00		0.00	
04. 2005	0.00		0.00		0.00	
05. 2005	0.00		0.00		0.00	
06. 2005	0.00		0.00		0.00	
07. 2005	0.00		0.00		0.00	

Tab. 6. Dominance of species *Amara aenea* in three different localities, during the investigated period

Таб. 6. Процентуално учество на видот *Amara aenea* во трите различни локалитети, во текот на истражуваниот период

месец	*Calathus cinctus*					
	R		S		U	
	доминантност		доминантност		доминантност	
07. 2004	8.10	SD	37.11	D	13.05	D
08. 2004	4.21	R	6.19	SD	5.36	SD
09. 2004	0.00		0.00		0.70	SR
10. 2004	2.59	R	3.09	R	1.40	R
11. 2004	0.49	SR	3.09	R	3.73	R
12. 2004	0.00		0.00		0.00	
02. 2005	0.00		0.00		0.00	
03. 2005	4.86	R	26.80	D	3.73	R
04. 2005	22.69	D	10.31	D	24.01	D
05. 2005	16.69	D	0.00		16.32	D
06. 2005	19.94	D	3.09	R	7.69	SD
07. 2005	20.42	D	10.31	D	24.01	D

Tab. 7. Dominance of species *Harpalus serripes* in three different localities, during the investigated period
Таб. 7. Процентуално учество на видот *Harpalus serripes* во трите различни локалитети, во текот на истражуваниот период

месец	*Calathus cinctus*					
	R		S		U	
	доминантност		доминантност		доминантност	
07. 2004	81.25	D	36.39576	D	23.747681	D
08. 2004	0		19.434629	D	12.059369	D
09. 2004	0		1.7667845	R	0.5565863	SR
10. 2004	0		0		0.9276438	SR
11. 2004	0		0		0	
12. 2004	0		0		0	
02. 2005	0		0		0	
03. 2005	0		0		0	
04. 2005	0		0		1.2059369	R
05. 2005	0		0		4.6382189	R
06. 2005	18.75	D	7.0671378	SD	12.059369	D
07. 2005	0		35.335689	D	44.805195	D