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Original scientific paper

ALTITUDE AND VEGETATION EFFECTS ON EPIGAEIC ARTHROPOD FAUNA FROM BELASICA MT. (SOUTH-EAST MACEDONIA) RUNNING TITLE: COMMUNITY STRUCTURE OF EPIGEIC MACROFAUNA ON BELASICA MT.

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Community structure of epigaeic arthropods along altitudinal gradient on Belasica Mountain was analysed. 140 pitfall traps were placed along a transect line at 14 sampling sites in the period April-November 2010. Altogether 6189 specimens were captured, belonging to 122 taxa (99 species and 23 morphospecies), 62 families, 14 orders and 5 classes. The largest contribution within fauna had beetle community (Coleoptera - 110 speices). Most numerous as expected were Coleoptera (44.76 %) and Araneae (32.47 %), followed by Diplopoda (7.86 %), Opiliones (5.97 %) and Isopoda (3.57 %).

The increasing altitude and differences of vegetation type (oak to beech forests) along the gradient influenced community structure with significant increase of the overall arthropod relative abundance. The highest relative abundance was registered in a submontane beech forest (1100 m a.s.l), while the lowest value was obtained in the locality dominated by the sessile oak forest (587 m a.s.l). The relative abundance of Aranea, Coleoptera, Diplopoda, Chilopoda, Microcoryphia and Blattodea increased with the elevation and significantly differed between localities and vegetation types, as well. Unlike them, the relative abundance of Scorpiones, Opiliones and Isopoda, significantly decreased along the gradient and consequently with differences of vegetation type. In contrast to the relative abundance, the overall species richness was influenced only by the increasing altitude.

Key words: epigaeic arthropods; elevation effects; Belasica Mt.; vegetation types

INTRODUCTION

Knowledge about ecosystem functioning and arthropod reactions to environmental changes is of conservation importance, especially in high mountain areas [10] and among other reasons especially because of the climate changes. According to [15] the studies documenting the present day altitudinal distribution of plants and animals will be an irreplaceable source for the estimation of ecological global warming effects. Additionally, to better understand biodiversity changes in mountainous ecosystems it is important to study how organisms are influenced by elevation and how they response to those changes.

Arthropods comprise many different functional guilds and are sensitive indicators of changes in environmental conditions [13]. Hence the aim of this study was to obtain basic knowledge of arthropod fauna, emphasizing their species richness, abundance and distribution range along altitudinal gradient at the northern part of Belasica Mt The boundary position of the mountain, the autochthonic plant communities and the influence of Mediterranean climate contributes to forming the complexes of many faunal, biogeographical and ecological elements of arthropod fauna.

The long term studies will improve the existing knowledge of epigaeic macrofauna on Belasica Mountain and further on other mountainous ecosystems in Republic of Macedonia.

MATERIAL AND METHODS

Area of research

Belasica Mountain is situated at the south-east part of Macedonia, bounded between Bulgaria and Greece (Figure 1). It belongs to the group of high mountains (over 2000 m) [6] and is among the smallest by area mountains in Macedonia. Belasica was formed as a mountain block during the Pliocene between two parallel seedlings bounded from north and south, rising as a horst between two sinking anticlinoria.

The mountain is build up mainly of metamorphic rocks–amphibolites, different types of minerals, granite, gneiss etc. Low parts of the mountain are characterized with cinnamon-forest soils, and at the higher parts most common are brown-forest and mountain-meadow soils. Climate in the low-mountain belt (300–1000 m) is mountain continental with Mediterranean influence, while the mountain belt over 1000 m alt. is influenced by the cold continental climate [7].

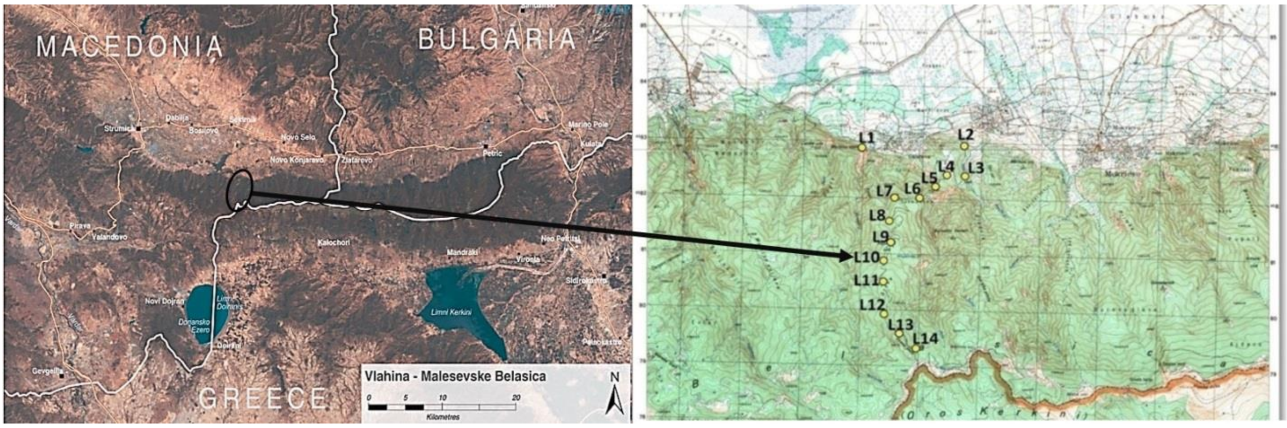


Figure 1. Topographic map of the investigated area and localities on Belasica Mountain

Sampling design

Fourteen localities (L1–L14) at different altitudes (240–1450 m a.s.l.) along an altitudinal gradient were selected at the north part of Belasica Mountain.

The vegetation cover is represented by several climazonal forests: first five localities (L1–L5) are covered by the association *Querco-Carpinetum orientalis macedonicum* Rudski apud Ht – Qqo (White oak and Oriental hornbeam); L6–L9 are dominated by the association *Orno-Quercetum petraeae* Em - Oqp (Sessile oak); L10 is disposed within the association *Festuco heterophyllae-Fagetum* - Fhf (Submontane beech forest); L10–L13 are allocated within the association *Calamintho grandiflorae-Fagetum* - Cgf (Montane beech forest), and L14 representing clear-cut area in a mountain beech forest.

The material was collected with pitfall traps placed along a 100 m long transect line. In each locality, one set contained of 10 pitfall traps was placed and traps were spaced 10 m apart from each other. In total 140 traps were placed in 14 different localities (L1–L14) referring to different altitudes on Belasica Mountain. Plastic cups were used as pitfall traps (volume of 0.5 L, diameter of 8.5 cm and height of 11.5 cm) and covered with metal rain-cover. Formaldehyde-vinegar solution (1:7; 200 ml) was used as a preservative. As pitfall-trapping is most appropriate method for collections of ground-dwelling fauna [17, 18], most of the samples were active dwellers on the soil surface and only those representatives were considered in the analysis.

The material was collected monthly, at the end of the month in the period April-November 2010. Data about the localities are presented in Table 1.

Table 1. List of the investigated localities with the data about the altitudes, GPS coordinates slope and dominant vegetation type

Code	Altitude (m)	Locality	GPS coordinates	Slope (%)	Vegetation cover (%)
L1	250 a.s.l.	near the locality of Markova Skala; ass. *Querco-Carpinetum orientalis macedonicum* Rud. 1939 ap. Ht. 1946	41°22'6.34"N 22°48'4.54"E	70	80
L2	327 a.s.l.	under the viewing point near the Koleshino Waterfall; ass. *Querco-Carpinetum orientalis macedonicum* Rud. 1939 ap. Ht. 1946	41°22'37.62"N 22°48'46.14"E	70	85
L3	415 a.s.l.	near the Koleshino Waterfall; ass. *Querco-Carpinetum orientalis macedonicum* Rud. 1939 ap. Ht. 1946	41°22'17.82"N 22°48'25.38"E	15	90
L4	500 a.s.l.	near the locality of Pod; ass. *Querco-Carpinetum orientalis macedonicum* Rud. 1939 ap. Ht. 1946	41°22'12.90"N 22°48'25.38"E	70	50
L5	587 a.s.l.	between the localities of Pod and Suva Cheshma ass. *Querco-Carpinetum orientalis macedonicum* Rud. 1939 ap. Ht. 1946	41°22'6.34"N 22°48'4.54"E	10	60
L6	693 a.s.l.	near the locality of Suva Cheshma; ass. *Orno-Quercetum petraeae* Em 1968 *(Fraxino orni-Quercetum petraeae* Em 1968)	41°22'3.87"N 22°48'13.20"E	40	90
L7	767 a.s.l.	near the locality of Popadija; ass. *Orno-Quercetum petraeae* Em 1968 *(Fraxino orni-Quercetum petraeae* Em 1968)	41°22'0.88"N 22°48'8.80"E	25	70
L8	847 a.s.l.	near the locality of Popadija; ass. *Orno-Quercetum petraeae* Em 1968 *(Fraxino orni-Quercetum petraeae* Em 1968)	41°22'0.88"N 22°48'8.80"E	15	90
L9	1038 a.s.l.	near the locality of Popadija; ass. *Orno-Quercetum petraeae* Em 1968 *(Fraxino orni-Quercetum petraeae* Em 1968)	41°22'0.88"N 22°48'8.80"E	20	95
L10	1100 a.s.l.	near the locality of Popadija; ass. *Festuco heterophyllae-Fagetum* (Em 1965) Rizovski & Džekov ex Matevski et al. 2011	41°22'0.88"N 22°48'8.80"E	25	85
L11	1200 a.s.l.	near the locality of Popadija; ass. *Calamintho grandiflorae-Fagetum* (Em 1965) Rizovski & Džekov ex Matevski et al. 2011	41°22'0.88"N 22°48'8.80"E	60	90
L12	1300 a.s.l.	near the locality of Groba; ass. *Calamintho grandiflorae-Fagetum* (Em 1965) Rizovski & Džekov ex Matevski et al. 2011	41°22'0.88"N 22°48'8.80"E	60	90
L13	1385 a.s.l.	near the locality of Pisana Skala; ass. *Calamintho grandiflorae-Fagetum* (Em 1965) Rizovski & Džekov ex Matevski et al. 2011	41°22'16.55"N 22°48'13.88"E	45	60
L14	1442 a.s.l.	near the locality of Pisana Skala; clear-cut area	41°22'0.88"N 22°48'8.80"E	25	60

Data analyses

Most of the arthropod specimens were identified to a morphospecies level. The specimens of orders Araneae, Chilopoda and Diplopoda were identified only to a family level. The exceptions are major part of order Coleoptera representatives identified to a species level, and only those specimens identified to a species and morphospecies level were included in the species richness analysis, while quantitative analyses were applied to all registered groups, including those identified to a family level.

Species richness and relative abundance were analyzed for each altitude and vegetation type along the gradient, and adult as well as larval stages were considered.

The relative abundance was represented as number of individuals per trap (ind.trap^{-1}). Dominance of species was calculated as a percentage of the number of individuals of a species in a total number of individuals of all species. Regarding their dominance species were classified in four groups: dominant species (D) over 10 %, subdominant species (SD) – 5–10 %, recedent species (R) – 1–5 % and subrecedent species (SR) – with the occurrence less than 1 % (Balogh 1958).

Shapiro-Wilks and Levene's tests were used to analyze the normality of distributions and homogeneity of variance, respectively. For normal distribution, data were log(x+1) transformed. But, because neither normal distribution nor homogeneity of the variance were recorded after the normality test was applied, non-parametric tests were applied: the nonparametric test Kruskal Wallis ANOVA as an analogue test of ANOVA and the post-hoc test Mann-Whithey U (which follows in cases where significant differences are recorded with the Kruskal Wallis ANOVA test). These tests were applied to check for the differences in average species richness and abundance within and between localities and vegetation types. These results are presented with box plots.

Spearman rank correlation (r) test was used to analyze the relationship between the altitude and species richness as well as average abundance of captured specimens.

All statistical data analyses were done with statistical program STATISTICA 6 for Windows. Significant values were those with $p<0.05$.

RESULTS AND DISCUSSION

The epigaeic arthropod fauna along the altitudinal gradient on northern slopes of Belasica Mountain was represented by 6189 individuals of 99 species and 23 morphospecies, belonging to 5 classes, 14 orders and 62 families. Among them, Insecta was represented with four orders (Coleoptera, Dermaptera, Blattodea, Microcoryphia), the class Arachnida with three (Opiliones, Scorpions and Araneae), two classes of Myriapoda (Chilopoda and Diplopoda) were present with six orders and the class Malacostraca was presented with one order only (Isopoda). The largest contribution had beetle community (Coleoptera - 110 species).

Considering the fact that the pitfall trapping method is associated with the underestimation of the abundance of flying (Diptera – 8.86 %, Hymenoptera – 3.64 %, Homoptera – 1.16 %, Lepidopera – 0.76 %, Orthoptera – 0.31 %, Hemiptera – 0.21 %, Neuroptera – 0.0033 %, Mantodea – 0.0016 %, Mecoptera – 0.0016 %), small sized (Collembola – 33.62 %, Acarina – 3.61%, Pseudoscorpiones – 0.33 %), larval stages (larvae of Lepidoptera – 1.85 %, Diptera – 0.62 %, Hymenoptera – 0.11 %, Neuroptera – 0.01 %) and slowly moving epigaeic representatives (Oligochaeta – 0.26 %, Gastropoda – 0.03 %), the same were excluded from the comparative analyses.

Although considerable differences of overall arthropod **species richness** between different forest types were not registered, the increasing altitude influenced community structure with decrease of species richness ($r = -0.190$, $p < 0.05$) throughout the gradient. Highest species richness (79) was registered in L6 (693 m a.s.l.), and the lowest (27) in L9 (1030 m a.s.l.), both localities dominated by sessile oak forest (Figure 2, A, B).

Low species richness in L9 was probably due to the lowest number of coleopteran species, while in general higher species richness in oak forests at lower altitudes is expected due to the favorable environmental conditions [1,3,4], often associated with higher temperature, as well as because of the greater habitat heterogeneity. According to [8], litter volume also, provides specific environmental conditions for epigaeic arthropods.

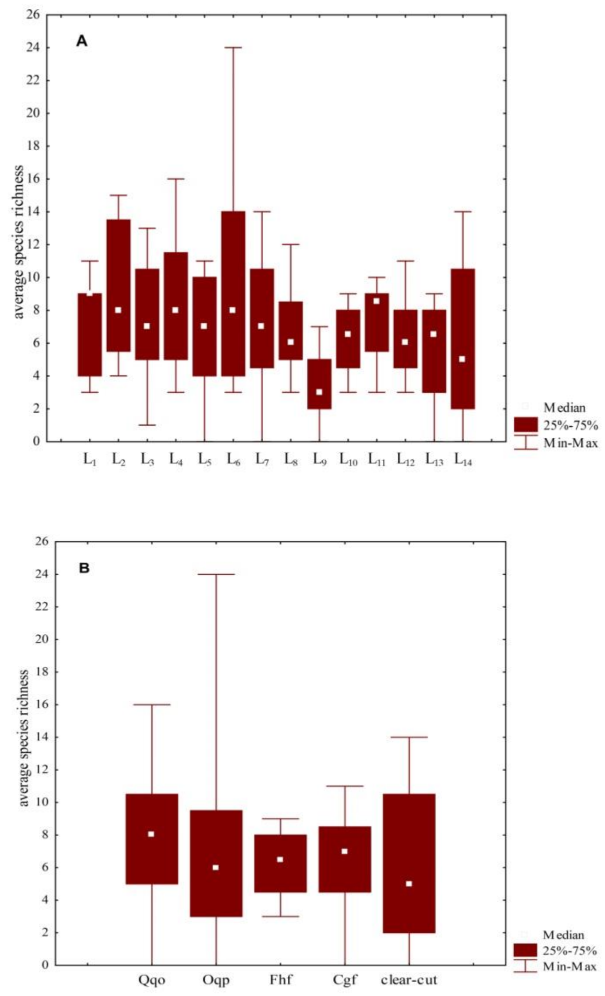


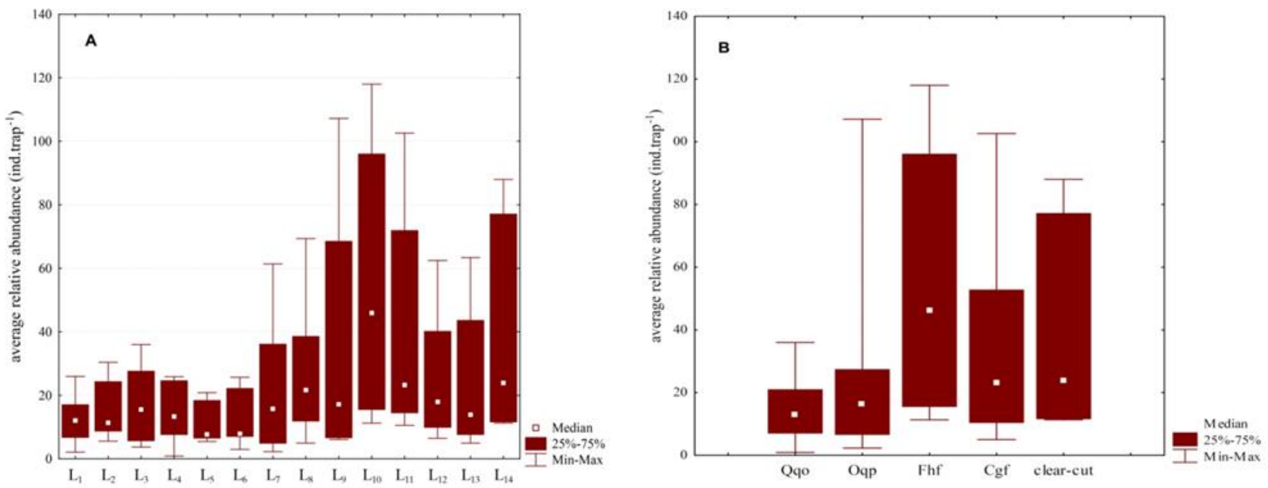
Figure 2. Average species richness of arthropod fauna a long altitudinal gradient A. and between different vegetation types B. on Belasica Mt.

Similar results were obtained by [16] in the research of diversity and abundance of soil invertebrates along an altitudinal gradient in the Silesian Beskid Mts (Western Carpathians), where diversity tended to decrease with altitude, and sites at higher elevations were poorer in invertebrate taxa.

The species richness of different arthropod groups did not change significantly along the gradient, neither with differences of vegetation structure along the same gradient. According to [21], changes of the species richness along the gradients vary depending on the taxonomic group that is studied.

The **relative participation** (%) of the specimens belonging to different arthropod groups is given on Figure 4. Most numerous as expected were Coleoptera (44.76 %) and Araneae (32.47 %), followed by Diplopoda (7.86 %) and Opiliones (5.97 %). Other representatives: Isopoda (3.57 %), Scorpiones (1.82 %) and Chilopoda (1.55 %) had recedent participation within the total arthropod fauna, and the remaining groups appear subrecendent with participation less than 1 % (0.99 % – 0.01 %).

The research of arthropod fauna showed significant differences of overall **relative abundance** between different forest types ($r = 0.300$, $p < 0.05$) and along the gradient ($r = 0.298$, $p < 0.05$), with significant increase throughout the same. Total arthropod abundance was higher in the localities from the upper altitudinal belt (L7–L14) especially in L9 (1038 m a.s.l.) and L14 due to the high relative abundance of spiders and L10 (1100 m a.s.l.) and L11 (1200 m a.s.l.) as a result of a high number of coleopterans. The highest relative abundance was registered in a submontane beech forest (Fhf) **-** L10 (1100 m a.s.l), while the lowest value was obtained in L5 (587 m a.s.l) dominated by sessile oak forest (Qgo) (Figure 3.A, B). In addition, [12], found that arthropod species richness and number of specimens in oak forests from northern Trace (Turkey) increased with elevation, also.



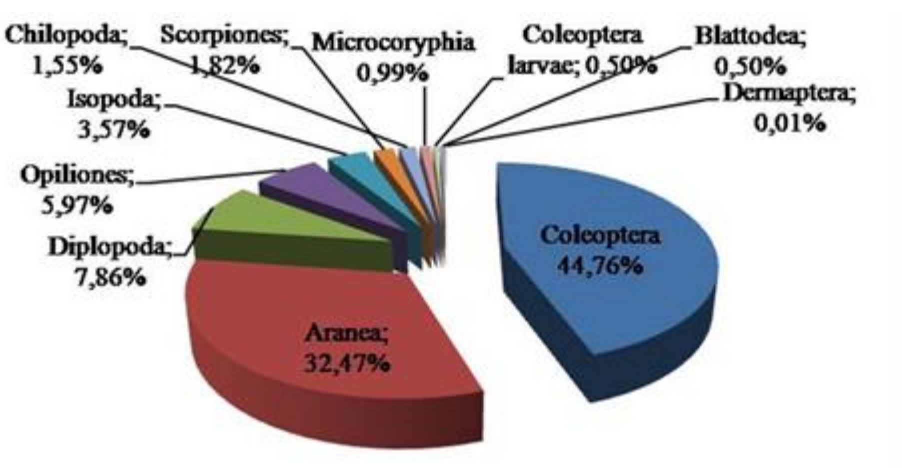


Figure 4. Relative participation (%) of different arthropod groups on Belasica Mt.

The relative abundance of Aranea ($r = 0.435$, $p < 0.05$), Chilopoda ($r = 0.202$, $p < 0.05$), Diplopoda ($r = 0.473$, $p < 0.05$), Microcoryphia ($r = 0.243$, $p < 0.05$), Coleoptera ($r = 0.200$, $p < 0.05$) and Blattodea ($r = 0.335$, $p < 0.05$) increased with the elevation and significantly differed between localities (Tab. 2) and vegetation types (Tab. 3). Coleoptera larvae also dominated at higher altitudes. The increased abundance of arthropods along the gradient was probably due to the low competition rate at higher altitudes. The abundance of spiders depends of the prey availability [14] which was probably more available at higher altitudes. With the exception of few localities dominated by the oak forests where their presence is recorded, microcoryphians occurred in higher abundance in the localities of the upper altitudinal belt. The same applies to Blattodea and to a certain level for centipedes whose abundance was higher in the upper part of the gradient. Millipedes preferred sub-mountain and mountain beech forests, but reached their highest values in the clear-cut area. Probably the milliped fauna from the clear-cut area is distinguished with different species composition from the previous, with domination of species which prefer more insolate and xeric condition. Identification on a species level is necessary in order to see which species determine the dynamics of the whole myriapod community.

The abundance of Scorpiones ($r = –0.693$, $p < 0.05$) Opiliones ($r = –0.208$, $p < 0.05$) and Isopoda ($r = –0.241$, $p < 0.05$), significantly decreased along the gradient (Tab. 2) and consequently with differences of vegetation type (from oak to beech forests and clear-cut area) (Tab. 3). In the research of [19, 20], altitude was also recorded as a factor limiting the distribution of millipedes and isopods. As previously stated by many authors, including [9, 14], with elevation, declining densities are expected due to decreased temperatures to suboptimal level, unfavorable conditions for larval development, reduced possibility of hibernation at higher altitude and reduced nutrients availability. In fact, not all species can adapt to unfavorable conditions which lead to low abundances at higher altitudes, and for the representatives of Arachnoidea is well known that prefer shadier habitats. The group of earwigs (Dermaptera) was represented by considerably low number of individuals which is probably due to the trapping efficacy of the pitfall method for active and surface dwelling species.

In conclusion, although Belasica Mt. is not very high, significant differences of community structure throughout altitudinal gradient were registered. While relative abundance of arthropods significantly increased with increasing altitude and differences of vegetation type (from oak to beech forest and clear-cut area), arthropod species richness was influenced only by the increasing altitude. Regarding the results of this study, certain arthropod groups could be used as potential bioindicators when analysing altitudinal influence on arthropods ecology and distribution in mountainous ecosystems.

Table 2. Annual relative abundance (ind.trap^{-1}) of arthropod groups along altitudinal gradient on Belasica Mt.

Relative abundance (ind.trap^{-1})	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**	**L10**	**L11**	**L12**	**L13**	**L14**
Aranea	1,75	2,83	2,30	3,23	3,45	4,90	4,16	11,82	**16,81**	13,77	12,01	10,29	8,38	**13,94**
Blattodea	0,00	0,00	0,04	0,00	0,09	0,04	0,03	0,41	0,16	0,25	0,03	0,04	0,09	0,58
Chilopoda	0,36	0,46	0,41	0,20	0,14	0,16	0,29	0,30	0,39	0,61	0,53	0,40	0,40	0,63
Coleoptera	5,88	7,68	6,81	6,39	**2,43**	5,58	13,31	9,88	10,89	**37,04**	**23,21**	12,29	8,36	9,09
Coleoptera larvae	0,10	0,14	0,30	0,43	0,20	0,01	0,00	0,01	0,01	0,09	0,11	0,03	0,00	0,06
Dermaptera	0,04	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Diplopoda	0,86	0,74	0,76	1,31	0,58	0,24	1,28	1,80	2,28	1,71	3,76	1,09	2,39	8,20
Isopoda	0,91	1,44	2,25	0,94	0,73	0,65	0,51	0,91	0,10	0,26	0,39	0,35	0,08	2,41
Microcoryphia	0,00	0,00	0,93	0,00	0,00	0,04	0,33	0,80	0,28	0,33	0,46	0,15	0,04	0,04
Opiliones	2,05	1,84	2,15	1,84	1,63	0,54	1,39	1,30	0,46	1,50	1,08	1,03	1,36	0,30
Scorpiones	0,55	0,51	1,25	0,44	0,89	0,75	0,88	0,11	0,03	0,00	0,00	0,00	0,00	0,00

Table 3. Annual relative abundance (ind.trap^{-1}) of arthropod groups in habitats of different vegetation type on Belasica Mt.

Relative abundance (ind.trap^{-1})	Querco-Carpinetum orientalis	Orno-Quercetum petraeae	Festuco hetero-phyllae-Fagetum	Calamintho grandiflorae-Fagetum	Clear-cut area
Aranea	**2,71**	9,42	13,77	10,22	13,94
Blattodea	0,06	0,16	0,25	0,05	0,58
Chilopoda	0,32	0,28	0,61	0,44	0,63
Coleoptera	5,84	9,91	**37,04**	14,62	9,09
Coleoptera larvae	0,23	0,01	0,09	0,07	0,06
Dermaptera	0,04	0,00	0,00	0,00	0,00
Diplopoda	0,85	1,40	1,71	2,41	**8,20**
Isopoda	1,25	0,54	0,26	0,27	**2,41**
Microcoryphia	0,93	0,36	0,33	0,22	0,04
Opiliones	1,90	0,92	1,50	1,15	0,30
Scorpiones	0,73	0,44	0,00	0,00	0,00

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ВЛИЈАНИЈА НА НАДМОРСКАТА ВИСОЧИНА И ВЕГЕТАЦИЈАТА ВРЗ АРТРОПОДНАТА ФАУНА НА ПЛАНИНАТА БЕЛАСИЦА (ЈУГОИСТОЧНА МАКЕДОНИЈА)

ПОДНАСЛОВ: СТРУКТУРНИ ОДЛИКИ НА ЕПИГЕЈСКАТА МАКРОФАУНА НА ПЛАНИНАТА БЕЛАСИЦА

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Извршена е анализа на структурните одлики на артроподната фауна по должина на височински градиент на северните делови од планината Беласица. За таа цел беа поставени вкупно 140 почвени замки по должина на трансект на вкупно 14 истражувани локалитети во периодот април-ноември 2010. Беа регистрирани вкупно 6189 единки кои припаѓаат на 122 таксони (99 видови и 23 морфовидови), 62 фамилии, 14 реда и 5 класи. Со најголемо видово разнообразие се издвојува тврдокрилната фауна (Coleoptera – 110 видови), додека најголем удел во вкупната абундантност на артроподите покажаа Coleoptera (44.76 %) и Araneae (32.47 %), по кои следуваат Diplopoda (7.86 %), Opiliones (5.97 %) и Isopoda (3.57 %). Зголемувањето на надморската височина и соодветните промени на вегетациската структура (промената од дабови кон букови шуми) по должина на градиентот, значително влијаат врз зголемувањето на вкупната бројност на артроподната фауна. Највисоки вредности беа евидентирани во локалитетот под доминација на подгорска бука, на надморска височина од 1100 m, а најниски на надморска височина од 587 m, каде доминира шума од благун и бел габер. Беа констатирани сигнификантни разлики во релативната бројност на Aranea, Coleoptera, Diplopoda, Chilopoda, Microcoryphia и Blattodea помеѓу одделните локалитети. Воедно овие групи покажаа сигнификатно повисока бројност во локалитетите под доминација на подгорска и горска бука, на повисока надморска височина. За разлика од нив, релативната абундантност на Scorpiones, Opiliones и Isopoda покажа значително намалување по должина на градиентот и воедно со преод од дабови кон букови шумски хабитати. Во споредба со вкупната бројност на артроподите, промените на вкупното видово разнообразие се резултат единствено на влијанието на надморската височина.

Клучни зборови: епигејски артроподи, Беласица, влијание на надморска височина,` вегетација