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Variation on ground-beetle communities (Coleoptera) in altitude gradient on Belasica Mt., Republic of North Macedonia

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Abstract

Community structure of ground-beetles along altitudinal gradient on a Submediterranean mountain in North Macedonia, bordered with Bulgaria and Greece was studied. The aim was to determine whether altitude influences the distribution and ecology pattern of ground-beetle community.

The research was carried out in 14 localities covering the main vegetation types on northern slopes of Belasica Mountain, by using pitfall traps.

The ground-beetle fauna consisted of 38 taxa and 7 subfamilies. Species richness and abundance of ground-beetles did not change significantly with increasing altitude and consequently with differences of vegetation type. But, the overall pattern of species diversity and homogeneity showed significant decrease towards higher altitudes indicating disruption of the community stability and presence of unfavorable conditions.

This study gives a preliminary analysis of the climatic mechanisms affecting ground beetle communities and indicates possible sensitiveness towards environmental changes along altitudinal gradient on Belasica Mountain.

Key words: Carabidae, vertical gradient, mountain, distribution and ecology pattern

Introduction

Belasica Mt. has boundary position in the south-east part of the country, with presence of rich floral and faunal complexes. This mountain is one of the most isolated areas with presence of well-preserved natural habitats and it is part of the Balkan green belt. Due to the abundance of natural habitats of great conservation importance, Greek and Bulgarian parts of Belasica are protected as „Natura 2000“. This mountain is declared as Nature Park in Bulgaria as well as National park in Greece, and is considered as Special Protected Area, according to the EC Birds Directive (79/409/EC). Unfortunately, in North Macedonia, Belasica Mountain does not have a status of protection.

Because of the south-eastern position in the country, Belasica Mt. represents the upper limit where the Mediterranean climate is present and is one of the first mountains in Republic of North Macedonia to be influenced by climate change, considering that these types of changes are particularly expected in the Mediterranean regions (Peñuelas et al. 2017).

In forest ecosystems, as a result of the altitude gradient, there are differences in the community structure among different altitude zones and habitats. This phenomenon is closely related to the spatial gradient of the physical factors of the environment, primarily determined by vegetation type. In most cases, altitudinal gradients has been analysed in order to: study biodiversity and its change along the gradient, to form a pattern of altitudinal zones, to perform a comparative

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analysis of the behaviour of different taxa along the same altitudinal gradient, to determine the causes why different groups respond differently to changes along gradients, to determine whether biodiversity changes continuously or intermittently, to analyse interactions between different taxa, etc.

This type of research has been carried out in a number of mountain ecosystems around the world, and the target group of the research, the method of work and the main objectives differ. Thus, for example, the change in the structure of the invertebrate community along altitudinal gradients has been studied by Olson (1994), Fleishman et al. (1998), Sanders (2002), Axmacher et al. (2004), Hausdorff (2006), Wilson et al. (2007), Nogués-Bravo et al. (2008), Müller et al. (2009); of birds: Doran et al. (2003), Altshuler (2006), Mccain (2009); on mammals: Mccain (2005), Mccain (2007), Rowe (2009); on plants: Frahm & Gradstein (1991), Wolf (1993), Odland & Birks (1999), Kessler (2001), Vetaas & Grytnes (2002), Grytnes & Vetaas (2002), Grytnes (2003), Fisher & Fulé (2004), Bachman et al. (2004), Kreft et al. (2004), Lovett et al. (2006), Grytnes et al. (2006), Erschbamer et al. (2006), Wang et al. (2007), Pauli et al. (2007), Behera & Kushwaha (2007), Shimono et al. (2010), Zhang et al. (2011) etc.

Often, a small number of taxonomic groups are used as bioindicators (McGeoch 1998). The family of ground-beetles (Coleoptera: Carabidae) abounds with species characterized by close attachment to certain microclimatic and soil conditions (stenobionts) and high bioindicative importance and representativeness. These arthropods are well-known indicators of environmental change (Stork 1990; Desender et al. 1991; Desender 1996; Niemelä 1996; Dufrěne & Legendre 1997). Furthermore, Brandmayr & Pizzolotto (2016) consider epigean and hypogean carabid beetles as excellent and „multitask" indicators of climate change.

According to Butterfield (1997), ground-beetles respond to changes by changing their habitat rather than changing their physiological adaptations, thus emphasizing their usefulness as favourable bioindicators of environmental changes. Looking back, there is a long history of their use as indicators of environmental change (den Boer 1977; Thiele 1977; Brandmayr 1980; Czechowski 1982; Klausnitzer & Richter 1983).

So far, no records exist about variations of terrestrial insect communities along altitudinal gradients in Republic of North Macedonia and at the same time we lack biodiversity and population data as important baseline information for measuring species population dynamics in the area. Also, there are no ecological studies of ground-beetles on Belasica Mt. related to changes of community structure throughout the altitudinal gradient and within habitat.

Regarding the hypotheses that altitude influences the distribution and ecology pattern of ground-beetle community on Belasica Mt., the aim of the study was to determine changes of species richness and community structure of ground-beetles along altitudinal gradient and consequently with differences of vegetation type on Belasica Mt. as first study which perform an ecological analysis of the carabid communities on this mountain and provide basic data for the future impacts of climate change and subsequent changes in vegetation structure, on animal communities.

Material and methods

Study site

The study was conducted on the northern slopes of Belasica Mountain at the south-east part of North Macedonia, at the border with Bulgaria and Greece (Fig.1). It is high mountain with an area of 198.2 km^2 (Melovski et al. 2013).

Lower parts of the mountain are with cinnamon-forest soils, and at the higher parts most common are the brown-forest and mountain-meadow soils (Filipovski et al., 1996). Climate at lower elevations (300-1000 m a.s.l.) is sub-Mediterranean (low precipitation rate and high temperature), while the mountain belt over 1000 m alt. is influenced by typical mountainous climate, characterized with higher precipitation and lower temperatures (Filipovski et al. 1996).

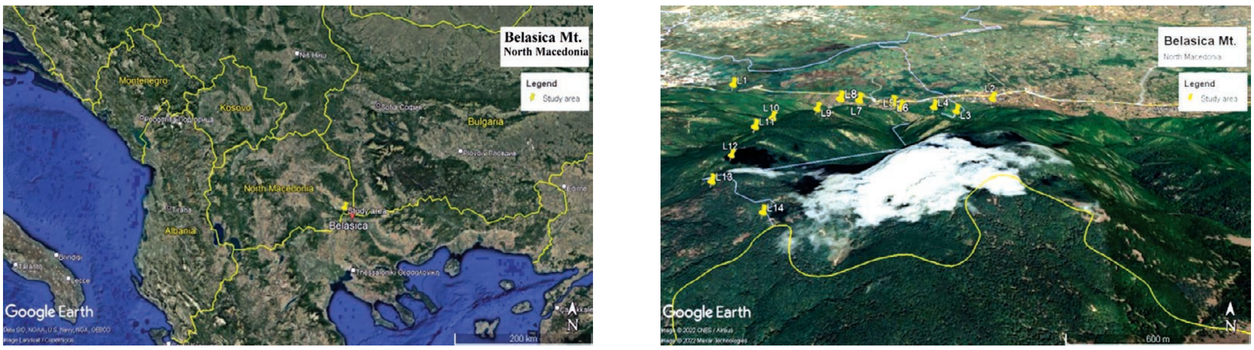


Figure 1. Topographic map of the investigated area on Belasica Mountain

Sampling design

Fourteen localities (L1-L14) at different altitudes (240-1450 m a.s.l.) along an altitudinal gradient were chosen (Fig. 1b), covering the main vegetation types represented by four climazonal forests. First five localities (L1-L5) are under forests of White oak and Oriental hornbeam; L6-L9 are under Sessile oak forest; L10 is disposed within submontane beech forest; L10-L13 are allocated within the montane beech forest, and L14 represents clear-cut area in a montane beech forest.

Beetle sampling

Ground-beetles were collected by pitfall traps (plastic cups with volume of 0.5 L, diameter of 8.5 cm and height of 11.5 cm) placed along a transect line following an isohypse. At each locality 10 pitfall traps were placed 10 m apart along a 100 m long transect line, thus covering each altitudinal zone. In total 140 traps were placed in 14 different localities (L1-L14) in vertical interval of 100 meters referring to different altitudes on northern slopes of Belasica Mountain. Traps were

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 pubescentis-Carpinetum orientalis* Horvatić 1939	41.382297 22.771482	70	80
L2	327 a.s.l.	under the viewing point near the Koleshino Waterfall; ass. *Querco pubescentis-Carpinetum orientalis* Horvatić 1939	41.377504 22.812616	70	85
L3	415 a.s.l.	near the Koleshino Waterfall; ass. *Querco pubescentis-Carpinetum orientalis* Horvatić 1939	41.372145 22.807476	15	90
L4	500 a.s.l.	near the locality of Pod; ass. *Querco pubescentis-Carpinetum orientalis* Horvatić 1939	41.371468 22.804530	70	50
L5	587 a.s.l.	between the localities of Pod and Suva Cheshma ass. *Querco pubescentis-Carpinetum orientalis* Horvatić 1939	41.370699 22.800324	10	60
L6	693 a.s.l.	near the locality of Suva Cheshma; ass. *Fraxino orni-Quercetum petraeae* Em 1968	41.368247 22.799759	40	90
L7	767 a.s.l.	near the locality of Popadija; ass. *Fraxino orni-Quercetum petraeae* Em 1968	41.369374 22.795384	25	70
L8	847 a.s.l.	near the locality of Popadija; ass. *Fraxino orni-Quercetum petraeae* Em 1968	41.366565 22.794000	15	90
L9	1038 a.s.l.	near the locality of Popadija; ass. *Fraxino orni-Quercetum petraeae* Em 1968	41.359571 22.794153	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	41.358462 22.790140	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	41.352880 22.791669	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	41.347933 22.792675	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	41.344122 22.793764	45	60
L14	1442 a.s.l.	near the locality of Pisana Skala; clear-cut area	41.341242 22.798297	25	60

placed in line with the soil surface and metal roofs were mounted above each trap to prevent flooding. Formaldehyde-vinegar solution (1:7; 200 ml) was used as a preservative.

The research was carried out monthly, during the period April-November 2010. The material was collected at the end of the month.

Data analyses

Species richness and the structure of carabidocoenosis were analysed for each altitude and vegetation type along the altitudinal gradient.

The abundance of ground-beetles 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 from a total number of individuals of all species. On the basis of dominance the species were categorised in four groups: dominant species (D) over 10%, subdominant species (SD) – 5-10%, recedent species (R) – 1-5% and subrecedent species (SR) – less than 1%.

Indices of richness-d (Margalef 1958), diversity – H' (Shannon-Wiener 1949) and homogeneity – $J_{(e)}$ (Pielou 1969) were used to compare alpha-diversity.

Statistical analysis was performed for the data of collected ground beetles at each altitude. Species abundance data were tested for normal distribution and variance of homogeneity by using Shapiro-Wilks and Levene's tests, respectively. To obtain normal distribution, data were log(x+1) transformed.

Nonparametric tests, Kruskal-Wallis, followed by post-hoc Mann-Whitney U tests (which follows when significant differences are recorded with the Kruskal Wallis ANOVA test) were applied to check for the differences in average species richness and abundance, within and between localities. These results are presented with box plots, which allow visual comparisons of centers and spread through the five-number summary (minimum, lower quartile, median, upper quartile, maximum), dividing the data into four equally sized sections (Pfannkuch 2006).

Spearman rank correlation (r_s) was used to analyse the relationship between the altitude and average number of captured species and specimens.

To test the efficacy of the sampling method and consequently to estimate the real versus estimated number of species, individual-based rarefaction was used (Gotelli & Colwell 2001, Hammer et al. 2013). This method is based on random re-sampling of the pool of captured individuals and plots the number of species versus a given number of individuals taken randomly from the observed data. With this method the number of species was rarified to the lowest values registered at a locality in order to provide valid information of species richness between different localities along the gradient.

To define groups of localities with similar species composition, Dice-Sorensen cluster analyse was used with UPGMA algorithm (Krebs 1999, Hammer et al. 2013). The similarity of relative abundance between different localities and vegetation types was compared with Bray-Curtis paired group cluster analysis (clusters were joined based on the average distance between all members in the two groups) (Somerfield 2008, Hammer et al. 2013). For calculating these indices, average species richness and relative abundance (ind·trap^{-1}) of ground-beetles between localities were used.

The species responsible for site clustering were established by using Principal component analyse (PCA) (Hammer et al., 2013).

All statistical data analyses were done with statistical programmes STATISTICA 7, PAST and XL stat for windows. Significant values were those with $p<0.05$.

Results

Overall 8680 individuals were collected belonging to 38 species, 18 genera and 7 subfamilies. Species composition is presented on Tab.2. *Tapinopterus balcanicus belasicensis, Carabus convexus dilatatus, Molops rufipes belasicensis,* and *Myas chalybaeus* had wide distributional range throughout the gradient, while the remaining species showed narrow altitudinal ranges as the same were found either in the localities from the lower or at the upper altitudinal belt, or were appearing discontinuously, in one or two localities.

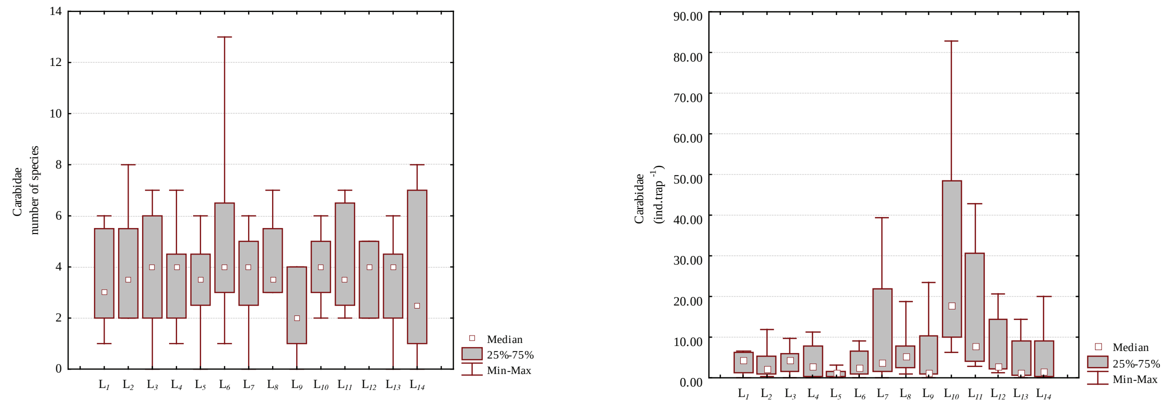
Tapinopterus balcanicus belasicensis (26,00%), *Carabus convexus dilatatus* (23,13%) and *Molops rufipes belasicensis* (16,70%) were dominant species, while most of the species had occurrence less than 5% of total catch (Tab. 2).

The studied carabid beetles' community have demonstrated high species richness and abundance. Although, the decrease of overall species richness and abundance with increasing altitude and changes of vegetation types (from oak to beech forests and clear cut area) was not statistically significant ($p>0.05$), considerable differences of species richness and abundance between localities were registered ($p<0.05$) (Fig. 2 a,b).

To estimate the number of species from each locality separately, rarefaction-method was used. For better visibility, the results are presented on two charts referring to lower and upper altitudinal range (Fig. 3. a,b), where the expected number of species is presented with red line, while 95% confidence interval with blue lines. This analysis showed that the expected number of species is highest in L5 (11.5), L6 (12.0) and L14 (8.5), and the lowest in L9 (4.0) and L10 (2.3), which confirms that the registered number of species on Belasica (presented in Tab. 2) almost equals to the expected number of species.

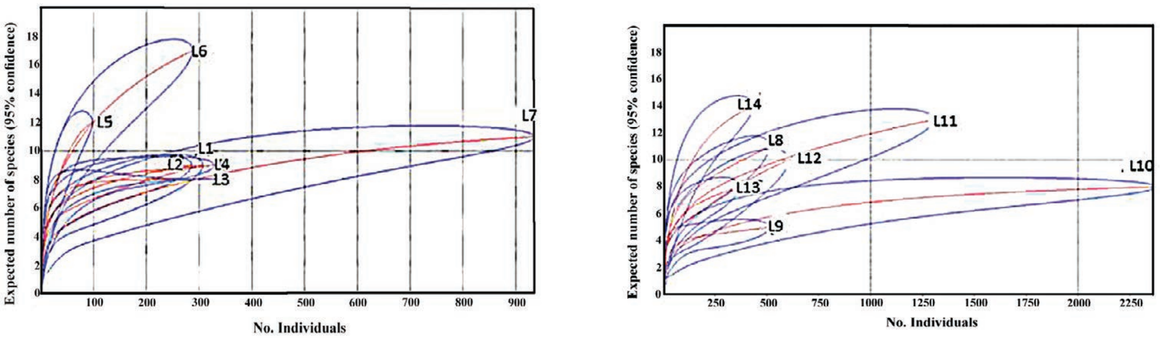
Table 2. Distributional range. abundance (ind·trap^{-1}) and dominance (%) of ground-beetle species along altitudinal gradient and dominant vegetation types on Belasica Mt.

species list	Querco-Carpinetum orientalis (Qgo)					Orno-Quercetum petraeae (Oqp)				Festuco heterophyllae-Fagetum (Fhf)	Calamintho grandiflorae-Fagetum (Cgf)			Clear-cut area	Abundance (ind·trap^{-1})	Dominance (%)	Dominance group
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14			
Tapinopterus balcanicus belasicensis	**0**	**0.43**	**0.39**	**0.16**	**0**	**0.18**	**0.53**	**3.85**	**3.01**	**21.24**	**9**	**3.41**	**2.06**	**0.29**	44.55	41.03	**D**
Carabus convexus dilatatus	**1.8**	**0.64**	**1.06**	**2.18**	**0.35**	**1.7**	**6.34**	**0.54**	**0.01**	**0**	**0.01**	**0.01**	**0**	**0**	14.64	13.48	**D**
Molops rufipes belasicensis	**0**	**0**	**0.85**	**0.54**	**0.04**	**0.19**	**0.53**	**1.48**	**3.06**	**7.64**	**5.29**	**3.08**	**1.45**	**0**	24.15	22.24	**D**
Myas chalybaeus	0.39	0.88	0.43	0.11	0.03	0.2	0.11	0.05	0	0	0.01	0.01	0	0	2.22	2.04	R
Harpalus tardus	0.04	0.06	0	0.01	0	0.01	0.01	0	0	0	0	0	0	0	0.13	0.12	SR
Calosoma inquisitor	0.41	0	0.26	0.74	0.03	0.65	4.04	0.08	0	0	0	0	0	0	6.21	5.72	**SD**
Carabus montivagus montivagus	0.16	0.34	0.11	0.06	0.01	0	0.03	0	0	0	0	0.01	0	0	0.72	0.66	R
Carabus intricatus intricatus	0.01	0.05	0.06	0.06	0.03	0.03	0	0	0	0	0	0.03	0	0	0.27	0.25	SR
Carabus coriaceus cerisyi	1	1.16	0.98	0.25	0.48	0.38	0.04	0	0	0	0	0	0	0	4.29	3.95	**SD**
Trechus quadristriatus	0	0	0	0	0	0.01	0	0.01	0.1	0.14	1.2	0.24	0.78	0.08	2.56	2.36	R
Cychrus semigranosus balcanicus	0	0	0	0	0	0.05	0	0.21	0.21	0.55	0.35	0.75	0.15	0	2.27	2.09	R
Nebria brevicollis	0	0	0	0	0	0	0	0.01	0	0.05	0.16	0.03	0.05	0.01	0.31	0.29	SR
Calathus fuscipes fuscipes	0	0	0	0	0	0.03	0.01	0.14	0	0.01	0.05	0	0	0	0.24	0.22	SR
Amara similata	0.01	0	0	0	0.03	0	0	0.01	0	0	0	0	0	0	0.05	0.05	SR
Amara aenea	0	0	0	0	0	0	0	0	0	0	0.03	0	0.01	0.05	0.09	0.08	SR
Harpalus atratus	0	0	0	0	0.03	0.01	0.04	0	0	0	0	0	0	0	0.08	0.07	SR
Harpalus honestus honestus	0	0	0	0	0.13	0.06	0	0	0	0	0	0	0	0.04	0.23	0.21	SR
Harpalus rufipalpis rufipalpis	0	0	0	0	0.09	0.03	0	0	0	0	0	0	0	4.43	4.55	4.19	**SD**
Synuchus vivalis	0	0	0	0	0	0	0	0	0	0	0.03	0	0.05	0.01	0.09	0.08	SR
Amara convexior	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.06	0.07	0.06	SR
Harpalus rubripes	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0.09	0.1	0.09	SR
Asaphidion flavipes	0	0	0	0	0	0	0	0	0	0.03	0.15	0	0	0	0.18	0.17	SR
Notiophilus substriatus	0	0.01	0	0	0	0.05	0	0	0	0	0	0	0	0	0.06	0.06	SR
Abax carinatus carinatus	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	SR
Amara curta	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.04	0.04	SR
Amara eurynota	0	0	0	0	0	0	0	0	0	0	0	0	0	0.26	0.26	0.24	SR
Calathus erratus erratus	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0.01	0.01	SR
Carabus violaceus azurescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0.03	0.03	SR
Carabus hortensis	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0.01	0.01	SR
Harpalus distinquendus distinquendus	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0.03	0.03	SR
Harpalus smaragdinus	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0.03	0.03	SR
Harpalus tenebrosus	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0.01	0.01	SR
Harpalus rufipes	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0.01	0.01	SR
Philorhizus notatus	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0.01	0.01	SR
Pterostichus niger niger	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0.01	0.01	SR
Pterostichus anthracinus	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	SR
Trechus subnotatus	0	0	0	0	0	0	0	0	0	0.05	0	0	0	0	0.05	0.05	SR
Trechus nigrinus	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.01	SR
Number of species	9	9	8	9	12	17	11	11	5	8	13	10	8	13			



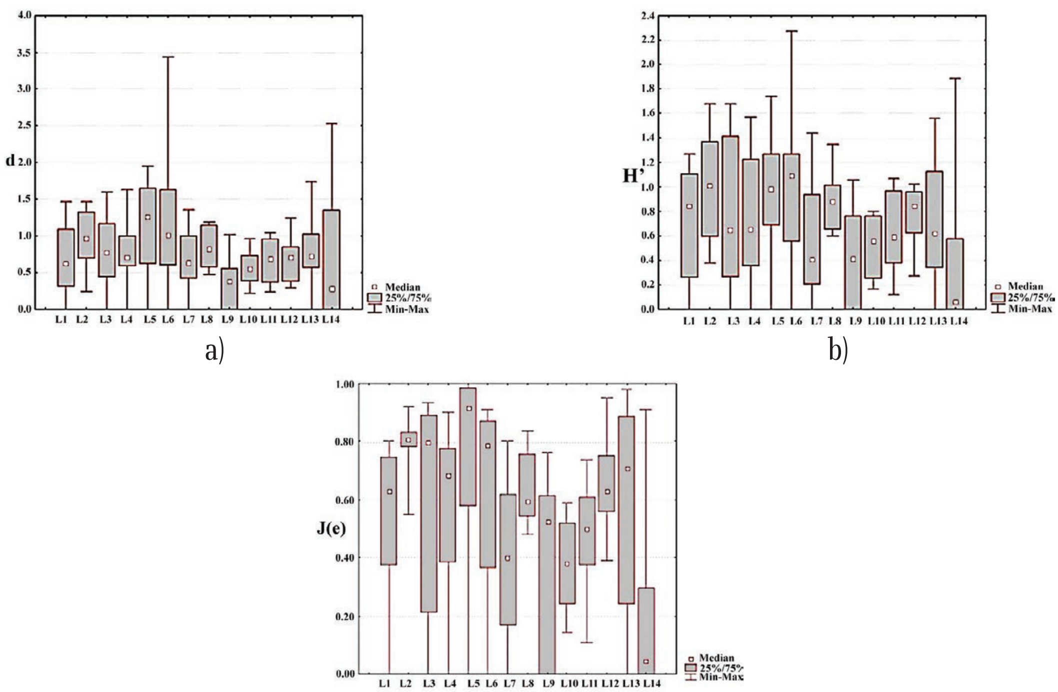
a) b)

Figure 2. Species richness a) and abundance (ind·trap^{-1}) b) of ground-beetle community along altitudinal gradient on Belasica Mt.



a) b)

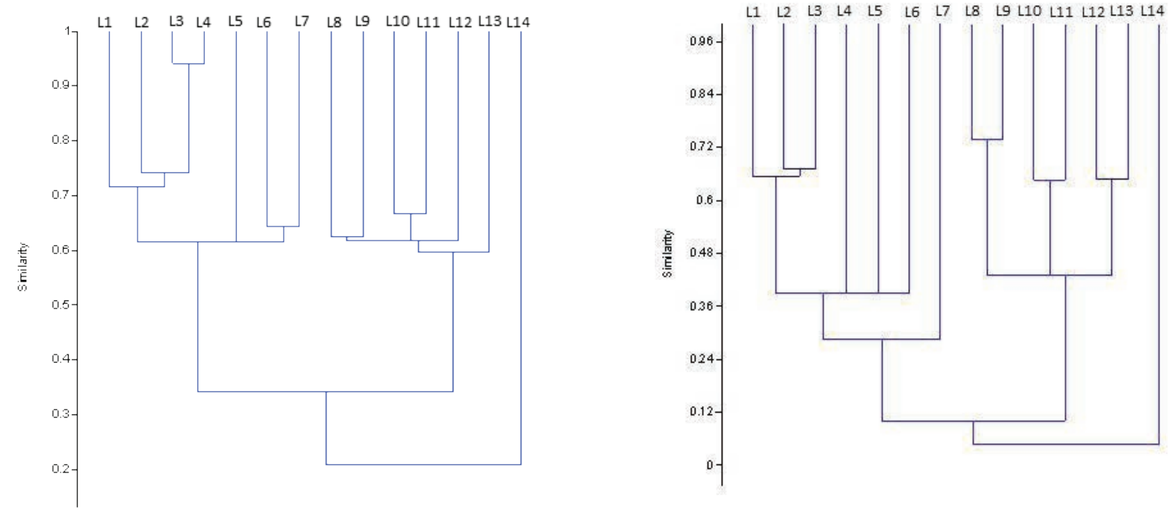
Figure 3. Rarefaction method – the expected number of species of a minimal sample of 100 randomly selected individuals from (a) – lower and (b) – upper altitudinal belt of Belasica Mt.



a) b)

c)

Figure 4. Indices of a) species richness, b) diversity and c) homogeneity of ground-beetle community along altitudinal gradient on Belasica Mt.



a) b)

Figure 5. UPGMA Dice-Sorensen cluster analysis for the presence-absence of species a), and Bray-Curtis paired group cluster analysis for similarity of ground-beetle abundance b), along altitudinal gradient on Belasica Mt.

Indices of richness and diversity were lowest for the carabidoenosis in L9, L10 and L14 causing lowest homogeneity thus emphasizing the existence of unfavourable conditions. Index of diversity was highest ($p<0,05$) in L2, L5 and L6 which contributes to highest values of homogeneity and the most stable populations in those habitats (Fig. 4 a,b,c).

Cluster analysis of ground-beetle composition based on the presence-absence of species, showed clear separation of beetle community from L14 in relation to other localities which were joined on approximately 35% level of similarity of their species composition (Fig.5a). First group includes communities inhabiting lower (L1-L7), and the second one, upper altitudinal belt (L8-L13).

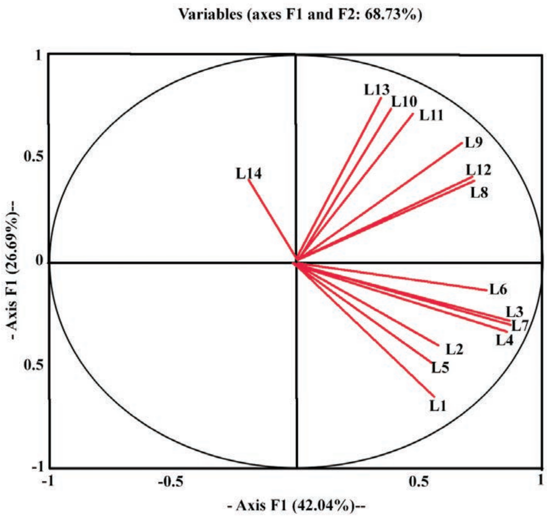


Figure 6. PCA ordination analysis of the distribution of species along altitudinal gradient on Belasica

When analyzing similarity of ground-beetle's abundance between different localities and vegetation types, two groups of localities were registered, L1 - L7 at 29% similarity level, and L8 - L13 at 42% similarity level, inhabited by carabidocoenosis similar in terms of quantitative composition (Fig.5b).

PCA ordination analysis of the distribution of species show correlation between the altitude and the abundance of some species. High relative abundance of *Calosoma inquisitor* ($R = -0,310$, $p<0,05$) and *Myas chalybaeus* ($R= -0,490$, $p<0,05$) contributed to the grouping of the communities from the lower altitudinal belt, while higher abundance of *Trechus quadristriatus* ($R= 0,431$, $p<0,05$) and *Cychrus semigranosus* ($R= 0,484$, $p<0,05$) separated communities at higher altitudes.

Discussion

The investigated area on the northern part of Belasica Mt. was characterized with relatively rich ground-beetle fauna, consisting of 38 taxa. Similar results were obtained in many other studies of ground-beetles in forest ecosystems: 10 - Yu et al. (2002), 43 - Taboada et al. (2004), 46 - Yu et al. (2006), 31 – Avgın (2006), 43 – Jiang (2006), 59 - Axmacher et al. (2011), 21 - Skalski et al. (2011), 31 Jelaska et al. (2011), 54 - Zou et al. (2014).

During the research, relatively high abundance was registered. Lower values were registered in the localities under oak forests in comparison to beech forests. Although general statement is that species richness and abundance in mountainous ecosystems decrease with increasing altitude (Lomolino 2001; Colwell et al. 2004; Dunn et al. 2007; Maveety et al. 2011; de Groot & Vrezec 2019), during this study the overall species richness and abundance did not change significantly with increasing altitude and consequently with differences of vegetation type.

Nevertheless, species composition of community showed changes with increasing altitude. Principal component ordination of ground-beetle abundance in relation to altitudinal gradient illustrates that altitude has influence on beetle assemblages and the overlap in assemblage composition was apparent among each locality and forest types. These differences were likely to be explained by the environmental variables primarily associated with climatic conditions along the gradient, as well as differences of vegetation type (Maveety et al. 2011; Ananina 2020; Ananina et al. 2021). Ground beetle communities depend on vegetation structure and soil morphology as well as on the altitudinal factor itself. This is the reason why ground-beetles have different altitudinal ranges in different mountains, or in different slopes of the same mountain, according to local climatic, pedologic and floristic conditions (Moret 2009).

When analyzing changes of the community structure along the gradient, the overall pattern of species diversity and homogeneity also showed significant decrease towards higher altitudes mainly as a result of significant differences of the abundance of dominant and subdominant species. According to Suttiprapan et al. (2006) dominant species have a wide niche breadth and can affect the patterns of richness, abundance and diversity. Lower values of species richness-d, diversity-H' and homogeneity-$J_{(e)}$ of the communities inhabiting upper altitudinal belt clearly indicate certain degree of degradation of the beech forest belt, especially in localities L9, L11-L13.

Dendrogram analyze defined groups of localities with similar species composition and abundance. In this way, the ordination grouping confirmed the importance of altitudinal effect and consequently the importance of vegetation type as abiotic factor.

The first group of localities was joined mainly by the presence of species (*Calosoma inquisitor, Myas chalybaeus, Harpalus tardus, Carabus coriaceus cerisyi, Carabus intricatus intricatus, Carabus montivagus montivagus*) preferring low altitude and old oak forests, in contrast to the second one, where localities are clustered by the presence of species *Trechus quadristriatus, Cychrus semigranosus balcanicus* and *Nebria brevicollis*, inhabiting beech forest, where higher precipitation and lower temperature prevail.

In L5 presence of *Harpalus honestus honestus* and *Harpalus rufipalpis rufipalpis*, as well as an absence of the subspecies *Tapinopterus balcanicus belasicensis* were registered. Also, the abundance of *Myas chalybaeus*, the dominant taxa *Carabus convexus dilatatus*, and especially *Molops rufipes belasicensis* and *Calosoma inquisitor* decreased resulting with significantly lowest total abundance of ground-beetles, in relation to all other localities along the gradient, which contributed to a significant decrease of domination (6.11%) and due to the reduced number of dominant taxa in this community, there is also a significant increase in the homogeneity (0.75).

Favorable conditions, such as well-preserved forest, suitable soil and air temperature and humidity in L6 and L7 caused increased number of dominant taxa, which contributed to a significant increase in the diversity index in L6 (1.01). L6 was inhabited by species which were registered in the lower altitudinal belt also. Some of those species have wider distribution and move to higher altitudes, mostly to L7 (767 m). Probably L6 (693 m a.s.l.) represents transitional zone between the ass. *Querco pubescentis-Carpinetum orientalis* and ass. *Fraxino orni-Quercetum petraeae*. Such habitats are predicted to harbor more species due to overlapping range limits or due to source-sink dynamics (McCain et al., 2010). In L7, due to the dominant role of *C. inquisitor*, the community's stability has been impaired, resulting in a significant decline in the homogeneity index (0.40) and the separation of carabidocoenosis of L7, from the communities inhabiting L1-L6 group (about 26%, see Fig.5b). In L7 the number of species is lower as a result of the absence of species which prefer forests of oriental hornbeam.

The similarity of communities inhabiting L8-L13 was due to the presence and relative abundance of *Tapinopterus balcanicus belasicensis, Carabus convexus dilatatus, Molops rufipes belasicensis, Cychrus semigranosus balcanicus, Nebria brevicollis* and *Trechus quadristriatus*. Environmental disturbance in the localities under beech forests (L8-L13) was caused by the intensified logging, which was most pronounced in the locality from the highest part of the gradient, L14, where clear-cut area exists. It must be pointed that the separation of carabodocoenosis from L14 is primarily due to habitat destruction and afforestation which have stronger effect then the altitude. L14 supports species that have colonised recently logged beech forest such as *Harpalus rufipalpis*. This species is not strictly connected to high altitude, but generally is an open area species and invades after forest disturbance.

This study gives a preliminary analysis of the climatic mechanisms affecting ground beetle communities and indicates possible sensitiveness towards environmental changes along altitudinal gradient on Belasica Mountain.

Conclusion

The overall pattern of decreased species diversity and homogeneity towards higher altitudes coupled with lower species asymptotes of rarefaction curves indicate that increasing altitude and consequently differences of vegetation type (from oak to beech forest and to clearcutted space) affects species composition and distribution of ground beetle communities.

The research of ground-beetle community structure clearly point up the presence of two habitat groups: those at lower altitudinal zones (240-767 m a.s.l) and habitats at higher altitude (847-1385 m a.s.l.), as well as marked separation of the clear-cut area (1442 m a. s.l.), which additionally confirms the importance of altitudinal effect and consequently the importance of vegetation type as abiotic factor.

We should point out that the results of this research can serve as a basis for further monitoring, especially research on the effects on animal communities caused by successive changes in the vegetation structure and the impact of climate change.

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