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The pattern of earthworm diversity on the western slopes of Kopaonik Mountain in Serbia: An empirical test of Rapoport's altitudinal rule

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Abstract:. The pattern of earthworm diversity along altitudinal gradients was rarely investigated. The aim of this study is to examine the patterns of earthworm diversity at on western slopes of the Kopaonik Mountain. Earthworm was sampled within four months in both 2018 and 2019 (from April to July). In total, 30 plots at altitudinal transects (between 420 and 1950 m a.s.l.) were sampled within two years' fieldwork. Overall, 27 earthworm species belonging to 11 genera were found at the study sites. A combination of Pearson's correlation, linear regression and cluster analysis (UPGMA) were used for determining the effects of altitude on the earthworm diversity. Essentially, we found monotonically declining relationships between total abundance/species richness and altitudinal gradients (from 14 to 6 species, and from 118 to 39 individuals). Cluster analysis revealed two patterns of earthworm community composition, one that characterizes lower altitude (up to 1000 m) and one that observed at the middle and higher altitude (from the 1000 m). Nevertheless, a major number of taxa with broader ecological tolerances which mean altitudinal range increased with increasing altitudes and thus supported the Rapoport's altitudinal rule, was observed. Overall, this study has provided new insights into the understanding of the effect of altitude on earthworm diversity.

Keywords: earthworm; altitudes; abundance; species richness; Rapoport's altitudinal rule

Introduction

Two diversity patterns (hump-shaped and monotonic decrease) frequently occur along altitude or latitude gradients. According to Rapoport's rule (Rapoport 1975), species diversity decreases with an increase in latitude (Stevens 1989) and altitude (Stevens 1992), because of a change in climate. However, more recent research shows that there are exceptions on this rule, where there is not any monotone decline in species richness, but a hump-shaped pattern with a peak in species richness at an intermediate elevation (Mishra et al. 2016, Betina et al. 2017). This phenomenon was termed the mid-domain effect (Colwel and Curt 1996). Most of the studies concentrated on plants and vertebrates along altitudinal gradients whereas invertebrates are understudied. The last years, investigations along the altitudinal gradient with main attention on soil invertebrates have been carried out (Schatz 2013, Mumladze et al. 2015). Concerning earthworms, the studies which have investigated earthworm fauna along altitudinal gradients done was in Australia (Wood 1974), South America (Feijoo et al. 2004, Gonzalez et al. 2007, Feijoo 2008, Cardoso et al. 2014, Gonzalez & Lodge 2017) and Korea (Tsai et al. 2004). Nevertheless, ecological studies which were researching the earthworm fauna along altitudinal gradients in Europe mountains are scarce, mostly limited to the study of on the Alps (Martinucci and Sala 1979, Salome et al. 2011), Carpathians (Plisko 1971, Kasprzak 1979, Kostecka and Skoczeń 1993, Rozen and Mvslajek 2005, Rozen et al. 2013) and the Khibiny Massive (Zenkova and Rapoport 2013). Therefore, this study aims to examine the patterns of earthworm diversity on western slopes Kopaonik Mt. Specifically, we addressed the following question: What are the patterns of total abundance and species richness along altitudinal gradients?

Study area

The Kopaonik Mt. (43°16'N, 20°49'E) is the largest mountain in Serbia, it is situated between the central and southern part of Serbia and belongs to the Dinaric mountain range (Fig. 1) .

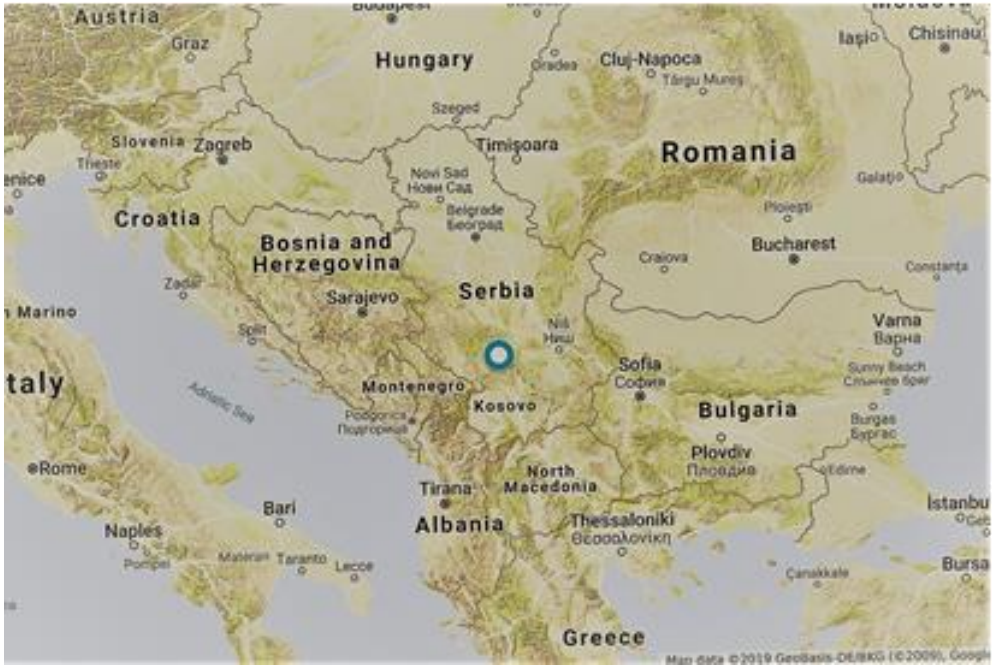

Figure 1. Geographic position of the Kopaonik Mt.

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Pictures of some sampling sites in this study.

Treska (1.666 m a.s.l.)

Semeteš (1.000 m a.s.l.)

Rtanj (1850 m a.s.l.)

Results and Discussion

The diversity of earthworm in western slopes Kopaonik Mt. shows the same patterns for total abundance and species richness. Both the total abundance and species richness of the earthworm fauna exhibited monotonically declining trends with increasing altitude (Fig. 2). Also, the abundance and species richness declined abruptly after 1.500 m altitude, probably due to tor low tolerance of taxa to high mountain harshness as well as changing pedological conditions. Pearson's correlation indicates a significant negative correlation between the altitude and species richness ($r = -0.96$, $p < 0.01$), as well as between altitude and total abundance ($r = -0.94$, $p < 0.01$).

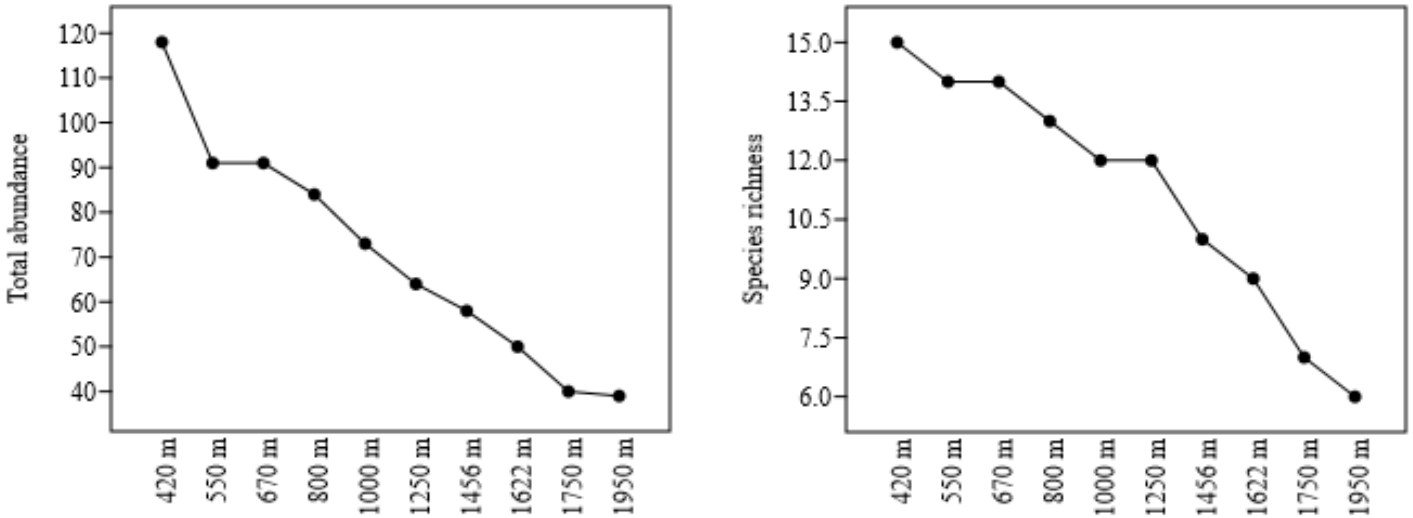

Figure 2. Relationship between earthworm species richness, abundance and altitude

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The cluster analysis of community similarity for earthworms revealed pronounced and distinct groups along the altitudinal gradient (Fig. 3). This indicates that the earthworm community composition pattern was strongly influenced by close vicinity, pedological conditions and vegetation cover.

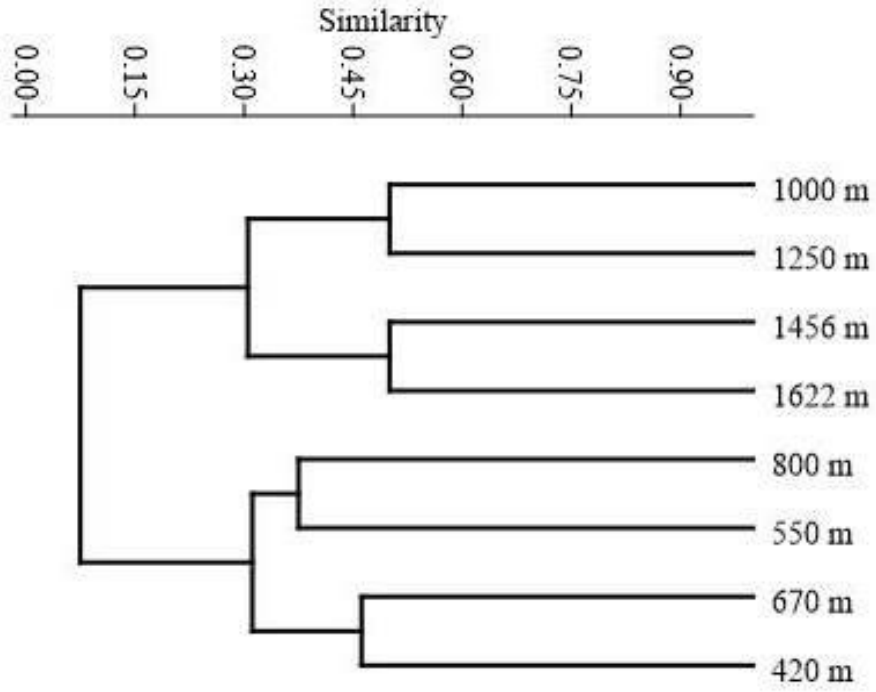

Figure 3. Cluster analysis (UPGMA) using the Jaccard's index of similarity among the altitudinal transects

The patterns in mean altitudinal range-size distributions showed a tendency of broader range-size distribution with increasing altitude (Fig. 4). Linear curve represented by a significant relationship ($r^2 = 0.30$, $p < 0.01$, Fig. 5). This is the result of broader ecological tolerances of the earthworm fauna, which favored the formation of the high-altitude taxa mainly by tolerant of taxa from lower altitudes. Also, our results showed that taxa from lower altitudes cannot be found at higher altitudes, as well that taxa covering broader altitude range have mostly higher abundances at a lower altitude.

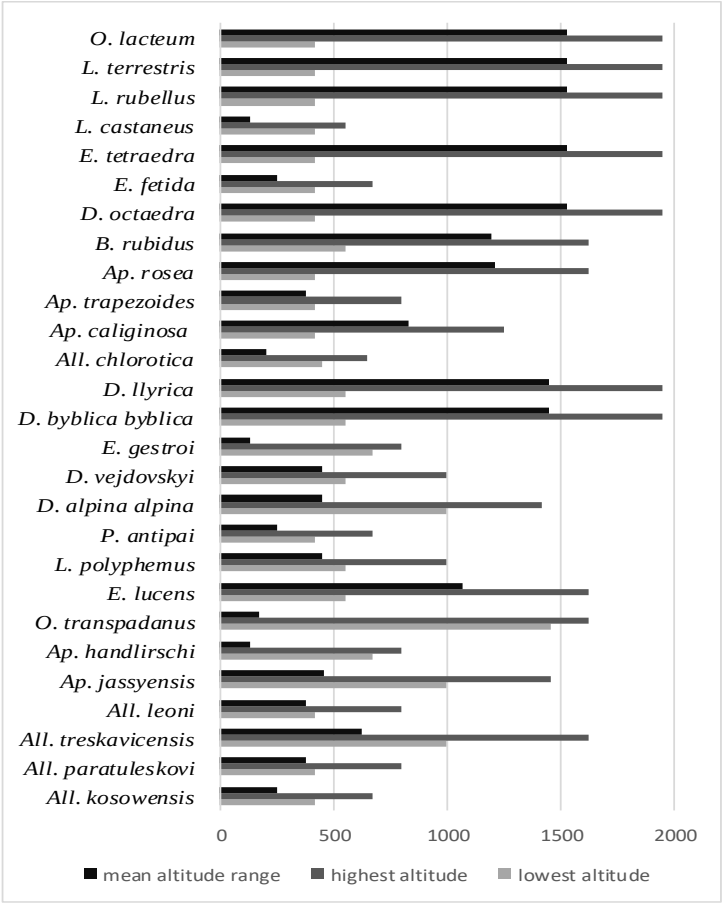

Figure 4. Altitudinal distribution ranges of earthworm taxa along

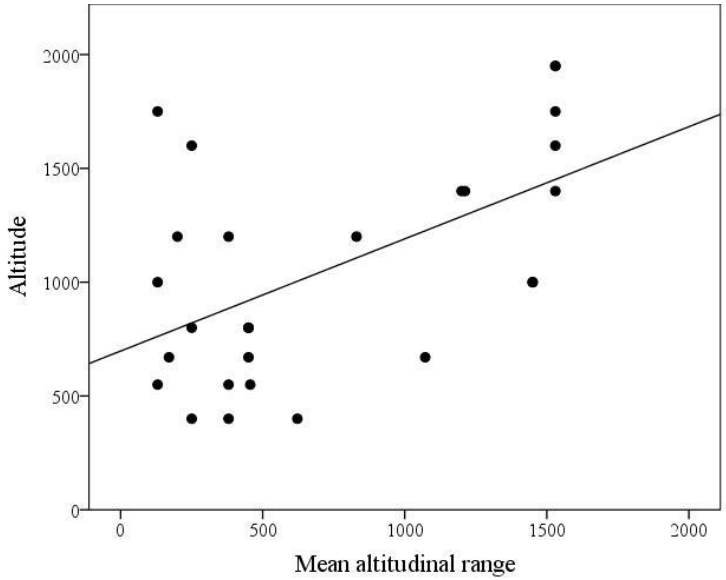

Figure 5. Altitudinal pattern of mean altitudinal range in altitudes

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Pictures of living specimens of some species of earthworms found during this study.

Lumbricus polyphemus (Fitzinger, 1833)

Proctodrilus antipai (Michaelsen 1891)

Allolobophora treskavicensis (Mršić, 1991)

Conclusion

This study indicates that western slopes Kopaonik Mt., is rich in the earthworm taxa, which decreased along the altitudinal gradients. This is because the optimum of environmental factors exist on lower altitudes and they can provide suitable habitats for the earthworm fauna. Nonetheless, was observed a major number of taxa with broader ecological tolerances, whose mean altitudinal range increased with increasing altitudes and thus was supported the Rapoport's altitudinal rule. However, there cannot exist a single model to describe how earthworm fauna reacts to the change in altitude, owing to further work is needed to test this controversial rule. Actually, due to their high diversity of earthworm fauna and the fact that they occupy a broader altitudinal range in the areas where they occur as well as important roles that these organisms have in the functioning of a variety of ecosystems, earthworms have a high potential as model organisms for this type of study. Therefore, we thus encourage other lumbricologists and ecologists to carry out similar studies to increase our limited understanding of the Rapoport's altitudinal rule of earthworm fauna.

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