POLISH JOURNAL OF ECOLOGY (Pol. J. Ecol.)	56	1	157–163	2008

Short research conribution

Slavomír STAŠIOV

Department of Biology and General Ecology, Faculty of Ecology and Environmental Sciences
Technical University in Zvolen, T. G. Masaryka 24, 960 01 Zvolen, Slovakia
e-mail: stasiov@vsld.tuzvo.sk

ALTITUDINAL DISTRIBUTION OF HARVESTMEN (EUCHELICERATA: OPILIONES) IN SLOVAKIA

ABSTRACT: The influence of altitude on the distribution of harvestmen (Opiliones) and on their species diversity in Slovakia was studied. The data were obtained from the numerous published sources and from the unpublished results of the author's own research activity. These basic results include the findings of 32 species from 680 localities, located unevenly in all the altitudinal vegetation zones of Slovakia at elevations from 107 to 2100 m a.s.l. The sampling area represents almost all the territory of Slovakia. The harvestmen were collected in a wide scale of various types of indigenous terrestrial biotopes including open land, forest ecosystems, agricultural country and urban habitats. The most of the studied species of harvestmen are distributed in a wide elevation range. The model of the altitudinal trend in the harvestmen species diversity has a shape of the single-peaked curve with the peak between 500 and 600 m a.s.l. The reduced richness of species at lower altitudes could be caused by the intensive agricultural activity in these regions. The range of area altitudinal zones 500–12 000 km^2 does not show a significant influence on the species diversity of harvestmen.

KEY WORDS: altitudinal distribution, harvestmen, Opiliones, Slovakia

Altitudinal variation in species distribution is a frequently documented ecological pattern. Two general trends in species richness-elevation relationship are apparent: a monotonic decrease in species richness with increasing elevation or unimodal relationship with a peak in richness at intermediate elevations. Despite the relatively large amount of information available in the faunistic papers, almost no attention has been paid to the influence of altitude on non-insect arthropods, particularly harvestmen (Opiliones). From among a few authors who paid the attention to the studies on the influence of this factor on harvestmen, Komposch and Gruber (1999), Stašiov and Bitušík (2001), Stašiov (2004) and Almeida-Neto *et al.* (2006) are to be mentioned.

Our aims were (i) to summarise altitudinal distribution patterns of harvestmen in Slovakia and (ii) to explore the variation in species richness along elevation gradient.

The approach of Zelený (1972), aimed at the mapping of Central Europe, was used in order to assess the distribution of harvestmen species in Slovakia. This mapping approach was accepted by the Databank of Fauna of Slovakia (DFS). Analysed data set was compiled through an extensive literature review

and own research results including 32 species from 680 localities in the altitude range from 107 to 2100 m a.s.l. Quantitative characteristics of harvestmen populations were difficult to estimate due to various sources of bias attributed to different sampling methods and level of effort. Harvestmen were sampled using following four methods: pit-fall trapping, individual collecting, dry sieve method from the leaf-litter and soil sampling. The meta-analysis was therefore based on presence/absence dataset. Descriptive methods using series of box plots were used to examine distributional ranges of each species. For purpose of diversity examination, studied altitudinal gradient was divided into twenty vertical intervals, each of 100 m. A species was assigned as present at every interval between the upper and lower elevation limits. Species richness was therefore defined as the number of species present in an altitudinal band. Since the different altitudinal bands do not represent equal areas and were not sampled with equal effort, the influence of area and sampling effort was taken into account in the analyses. An exact area of each altitudinal band was derived from 1:50 000 scale digital elevation model (Fig. 2A). Sampling effort was defined as the number of sampling sites in each altitudinal band (Fig. 2B). Relationship of harvestmen species richness to altitudinal gradient was analysed by multiple regression using generalized linear models (GLMs). As the response variable was in the form of counts (number of species) a Poisson error distribution with a log link function was used for regression. The minimum adequate model (Crawley 1993) for species richness was found by deleting variables with no significant effect from the maximal model, which left those predictors whose deletion caused significant increase of deviance (χ^2 test, p <0.01). The maximum model included altitude, area, sampling effort and their quadratic terms as predictors of harvestmen species richness. Hierarchical partitioning (Chevan and Sutherland 1991) was used to identify the 'independent' explanatory power of first order predictors to the species richness. The significance was tested by 1000 randomisations based on upper 0.95 confidence limit (Mac Nally 2002).

Based on the collections from 680 localities in total, the occurrence of 32 harvestmen

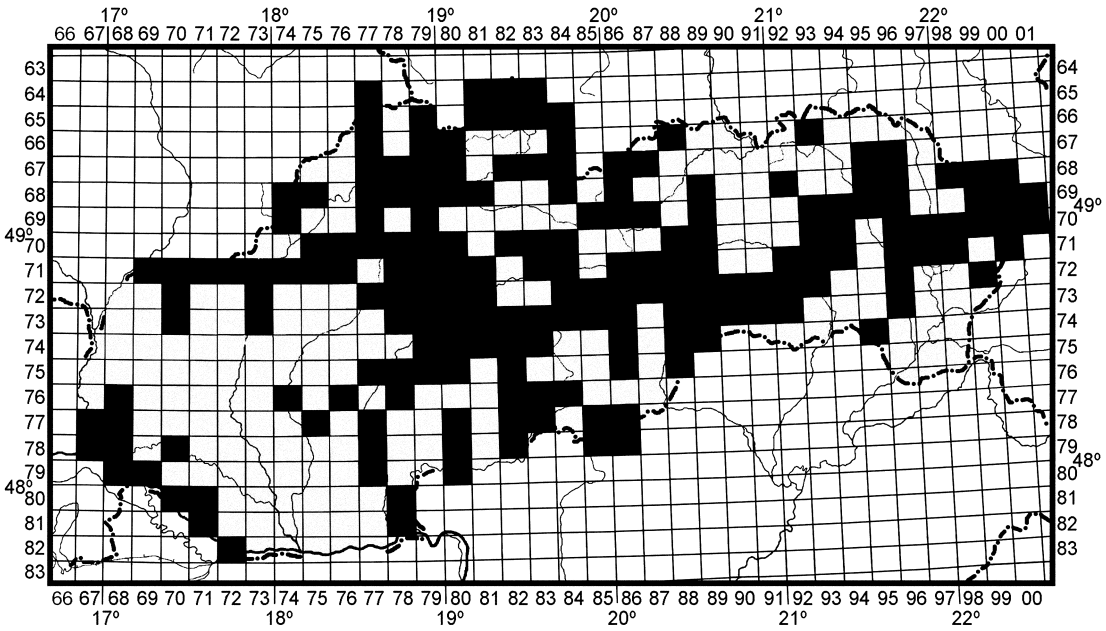

Fig. 1. Map of Slovakia with the marked quadrats of Databank of Fauna of Slovakia, where collections of harvestmen were carried out up to now.

species from 7 families was reliably documented from the territory of Slovakia (one species has been determined at the level of genus).

Territory of Slovakia covers 431 quadrants of DFS. From among those, 301 quadrants fall completely under the Slovak territory and 130 quadrants include neighbouring countries as well. Up to now, the harvestmen were collected from 187 quadrants of DFS (43% of total number of quadrants) (Fig. 1). From among 84 geomorphologic units in Slovakia, samples of harvestmen were obtained in 65 (77% of Slovak geomorphologic units).

Territory of Slovakia involves the elevation range from 94 m a.s.l. (Bodrog river in South Slovakia) to 2655 m (Gerlach peak in High Tatra Mts.). The lowest localities in Slovakia, where the harvestmen were collected, are located in the Podunajská nížina lowland at the altitude of 113 m a.s.l. (Gulička 1957, Majzlan and Hazuchová 1997). The highest site with the collection of harvestmen lies at the altitude of 2100 m a.s.l. under the summit of Kriváň peak in High Tatra Mts. (Stašiov 2004).

The lowest altitudinal band (100–200 m a.s.l.) covers the largest surface area of Slovakia (Fig. 2A).The area covered by the second band (200–300 m a.s.l.) is more than one third smaller than the first band. Total surface area decreased with increasing altitude. The highest sampling effort was in altitudinal band ranging from 300 to 400 m a.s.l. (Fig. 2B). The area of seven bands (300–1000 m a.s.l.) can be considered as relatively well-investigated because each altitudinal band included at least 50 sampling sites.

On the territory of Slovakia, the harvestmen were collected in a wide range of various terrestrial biotopes with the suitable life conditions. These biotopes represent various types of open and afforested land, agricultural country and urban ecosystems. An enhanced attention was engaged to the research of opiliofauna in protected areas.

Majority of the harvestmen (19 species) had altitudinal distribution range wider than 1000 m, where *Mitopus morio* (Fabricius, 1799) occurred throughout the whole range (Fig. 3). Nine species (*Astrobunus laevipes* (Canestrini, 1872), *Egaenus convexus* (C. L. Koch, 1835), *Lacinius dentiger* (C. L. Koch,

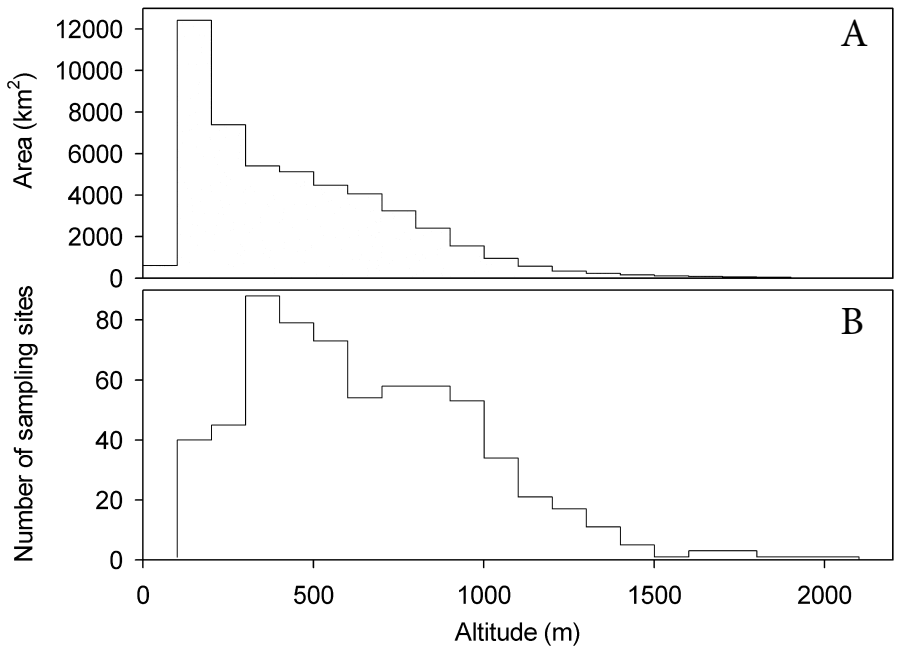

Fig. 2. Area (A) and sampling effort expressed as a number of sampling sites (B) of each investigated altitudinal band.

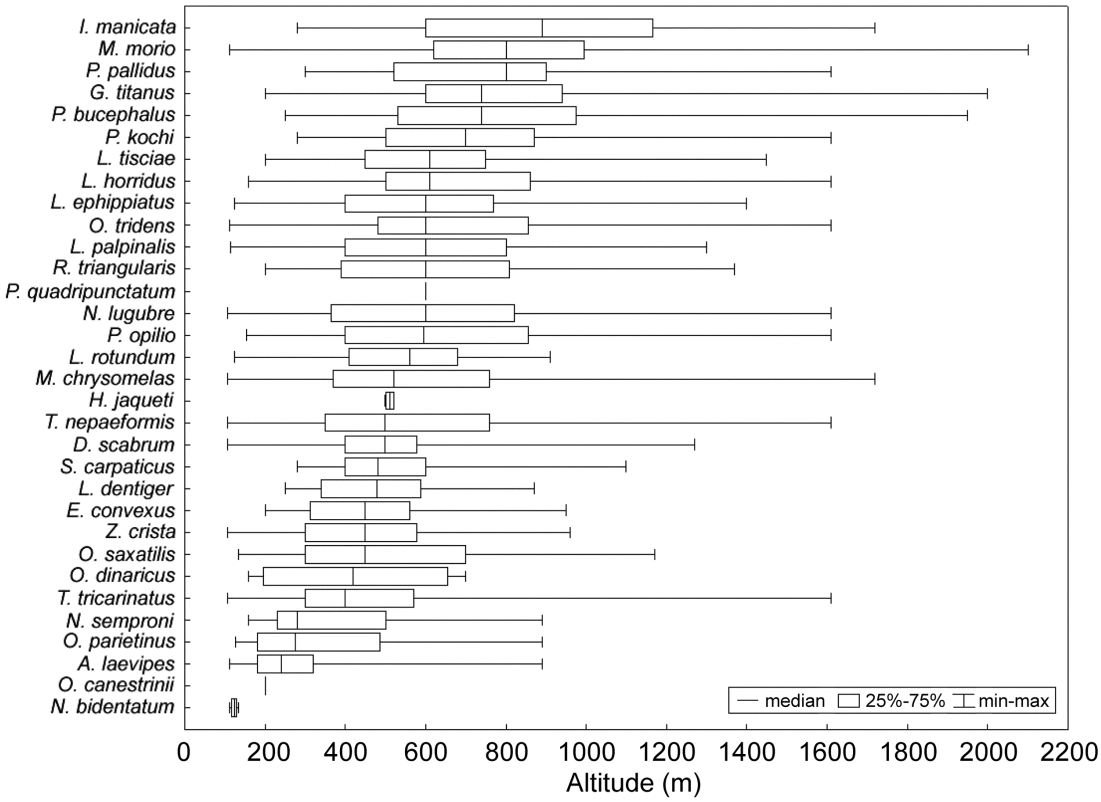

Fig. 3. The altitudinal ranges of harvestmen (Opiliones) species in Slovakia compiled through a literature review. Number of sampling sites with species occurrence are given in parenthesis. Species: *Astrobunus laevipes*, *Dicranolasma scabrum*, *Egaenus convexus*, *Gyas titanus*, *Holoscotolemon jaquet*, *Ischyropsalis manicata*, *Lacinius dentiger*, *L. ephippiatus*, *L. horridus*, *Leiobunum rotundum*, *L. tisciae*, *Lophopilio palpinalis*, *Mitopus morio*, *Mitostoma chrysomelas*, *Nelima semproni*, *Nemastoma bidentatum*, *N. lugubre*, *Oligolophus tridens*, *Opilio canestrinii*, *O. dinaricus*, *O. parietinus*, *O. saxatilis*, *Paranemastoma kochi*, *P. quadripunctatum*, *Phalangium opilio*, *Platybunus bucephalus*, *P. pallidus*, *Rilaena triangularis*, *Siro carpaticus*, *Trogulus nepaeformis*, *T. tricarinatus*, *Zachaeus crista*.

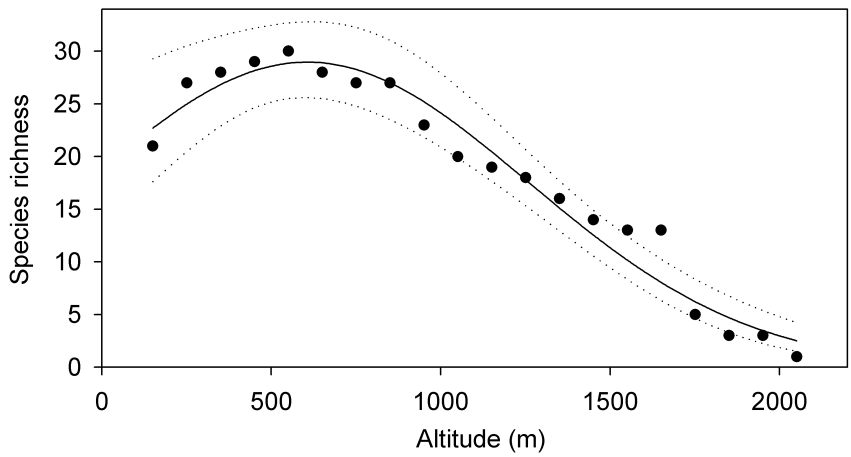

Fig. 4. Harvestmen species richness in relation to altitude. The lines represent fitted values 95% CL. The fitted line (95% CL) is based on a second order polynomial regression using a GLM.

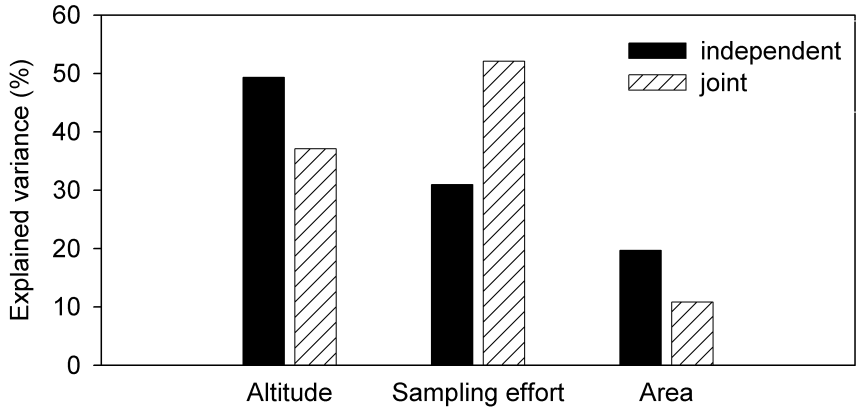

Fig. 5. The independent and joint contributions of the predictors to the harvestmen species richness. Independent contributions are in black, while joint contributions are hatched. Asterisks indicated significant results after 1000 randomizations. Area – area range of each altitudinal band (see Fig. 1). Sampling effort – expressed as a number of sampling sites in each band (see Fig. 1).

1848), *Leiobunum rotundum* (Latreille, 1798), *Nelima semproni* Szalay, 1951, *Opilio dinaricus* Šilhavý, 1938, *Opilio parietinus* (De Geer, 1778), *Siro carpaticus* Rafalski, 1956 and *Zachaeus crista* (Brullé, 1832) occupied relatively narrow interval of altitudinal bands (900–600 m). Remaining 4 rare species (*Holoscotolemon jaqueti* (Corti, 1905), *Opilio dinaricus* Šilhavý, 1938, *Opilio canestrinii* (Thorell, 1876), *Dicranopalpus* sp. Doleschall, 1852) were found within single or two sites in Slovakia (Fig. 3).

Sequential deletion of variables from the full model left a minimum adequate model that explained 94% of the total deviance in species richness and included altitude and its squared term ($\chi^2 = 56.35$, $P < 0.001$) (Fig. 4). Species richness showed clear unimodal response along the altitudinal gradient. It increased from 100 to 500 m a.s.l. Between 500 and 600 m a.s.l., there is a peak of richness and beyond 600 m a.s.l. it decreased gradually towards higher altitudes. When rare species were excluded from analysis, observed pattern remained unchanged (Fig. 4).

Hierarchical partitioning revealed that altitude had largest independent effect and area had the weakest independent effect (Fig. 5). Sampling effort had large joint effect due to high correlation with altitude.

In terms of hypsometric distribution, most of harvestmen were characterised by a relatively high degree of their tolerance towards the altitude. The relatively narrow altitudinal amplitude of localities where some rare species were found seems to be rather a result of our insufficient information on the distribution of these species than of their real stenoecy.

With an exception of *Siro carpaticus* Rafalski, 1956, all the species with a relatively closer relationship to the elevation were found at lower or middle altitudes (below 1000 m a.s.l.)

Except for the harvestman *H. jaqueti*, which is insufficiently examined from viewpoints of its hypsometric distribution in Slovakia, all the studied species have the lower limit of their distribution in Slovakia below 300 m a.s.l. Even the species with the ecological optimum at higher elevations are thus able to exist at lower altitudes as well (e.g. in valleys with the inversion microclimate or on the other suitable localities). On the territory of Slovakia, the upper limit 1700 m a.s.l. was exceeded by *Gyas titanus* Simon, 1879, *Ischyropsalis manicata* L. Koch, 1865, *Mitostoma chrysomelas* (Hermann, 1804), *M. morio* and *Platybunus bucephalus* (C. L. Koch, 1835).

The results of Komposch and Gruber (1999) from 13 localities (900–3300 m a.s.l.) in eastern Alps demonstrated the different tolerance towards the altitude for the various harvestmen species. In the accordance with our findings, the cited authors referred to the great ecological plasticity in requirements on the elevation for *M. morio*. In addition, they observed the high tolerance towards the

altitude for the harvestman *M. chrysomelas*. This fact corresponds to its distribution in a wide altitudinal range, in Slovakia as well. From among another species known from the territory of Slovakia, Komposch and Gruber (1999) demonstrated the lowest tolerance towards the altitudinal range for *Opilio saxatilis* C. L. Koch, 1839, *Lophopilio palpinalis* (Herbst, 1799) and *Leiobunum tisciae* Avram, 1968. In Slovakia, however, all the mentioned species are characterised by a much higher tolerance towards the elevation and occur in a much wider altitudinal range.

The observed culmination of the harvestmen species richness at the altitudes of 500 to 600 m a.s.l. could be related to the natural distribution of beech (*Fagus sylvatica* L.) on the territory of Slovakia. Namely, this range of altitudes falls within the beech forests (*Querco-Fagetea* (Braun-Blanquet 1964) altitudinal zone with the dominance of this woody plant. The beech forests stands are characterised by a relatively high and stable humidity of soil, a very important factor, playing a crucial role in the harvestmen distribution. Indeed, the humid deciduous and mixed Slovak forests with the dominant occurrence of beech are also characterised by the maximum species richness of harvestmen (10 species from the total number of 32 species known from the territory of Slovakia). The second richest group is represented by the harvestmen of xerothermic broad-leaved and mixed forests and their ecotons (7 species) and the third one (4 species) involves the euryvalent harvestmen (Stašiov 2004). Contrariwise, the lower species richness of the harvestmen from localities below 500 m a.s.l. is probably influenced by the flat or hilly country with the intensive agricultural exploitation. The agrotechnical and agrochemical interventions have a strong negative influence on the distribution of harvestmen. Most of the species avoid this habitat.

Almeida-Neto *et al.* (2006) studied the influence of the elevation on the species diversity of harvestmen along three altitudinal gradients in a maritime forest stand in the South-Eastern region of Brazil (the vicinity of Sao Paulo). The results of their studies demonstrate that the abundance and species richness of harvestmen decreased with the increasing altitude and the decreasing temperature and humidity. During the dry and cold period, the harvestmen fully absented over 750 m a.s.l.

ACKNOWLEDGEMENT: I am grateful to Marek Svitok (Technical university in Zvolen) for statistical analysis of data and visualisation of the results. The author would like to thank Lívia Olahová (Technical university in Zvolen) for valuable help with the GIS analysis. This study was supported by the Slovak grant agency VEGA, grant number GE – XVII/3017.

REFERENCES

Almeida-Neto M., Machado G., Pinto-da-Rocha R., Giaretta A.A. 2006 – Harvestman (Arachnida: Opiliones) species distribution along three Neotropical elevational gradients: an alternative rescue effect to explain Rapoport's rule? – J. Biogeogr. 33: 361–375.

Braun-Blanquet J. 1964 – Pflanzensoziologie-Grundzuge der Vegetationskunde – Springer Verlag, Wien, 865 pp.

Chevan A., Sutherland M. 1991 – Hierarchical partitioning – The American Statistician, 45: 90–96.

Crawley M.J. 1993 – GLIM for ecologists – Blackwell Science, Oxford, 392 pp.

Gulička J. 1957: Kvalitatívno-kvantitatívny rozbor pôdnej fauny Čierneho lesa (Ostrov) (Myriapoda, Isopoda, Opiliones) [Qualitative and quantitative analysis of soil fauna at the Čierny les (Island), (Myriapoda, Isopoda, Opiliones)] – Acta Fac. Rer. Nat. Univ. Comeniana, Zool. 2: 119–139. (in Slovak, English summary).

Komposch Ch., Gruber J. 1999 – Vertical distribution of harvestmen in the Eastern Alps (Arachnida: Opiliones) – Bull. Br. arachnol. Soc. 11/4: 131–135.

Mac Nally R. 2002 – Multiple regression and inference in ecology and conservation biology: further comments on identifying important predictor variables – Biodivers. Conserv. 11: 1397–1401.

Majzlan O., Hazuchová A. 1997 – Abundancia a sezónna dynamika koscov (Opiliones) v pôde lužných lesov Podunajska [Abundance and seasonal dynamics of the harvestmen (Opiliones) in soils of the Danube lowland] – Folia faunistica Slovaca, Bratislava, 2: 47–51. (in Slovak, English summary).

Stašiov S. 2004 – Kosce (Opiliones) Slovenska [Harvestmen (Opiliones) of Slovakia] – Sci-

entific studies, Technical university in Zvolen, Zvolen, 119 pp. (in Slovak, English summary).

Stašiov S., Bitušík P. 2001 – Rozšírenie troch skupín epigeickej makrofauny pozdĺž výškového gradientu v doline Nefcerka (Vysoké Tatry): kosce (Opilionida), mnohonôžky (Diplopoda), stonôžky (Chilopoda) [Distribution of three epigeic macrofauna groups along an altitudinal gradient in Nefcerka Valley (the High Tatra Mts., Slovakia): harvestmen (Opilionida), millipedes (Diplopoda), centipedes (Chilopoda)] – Acta Fac. Ecologiae, 8: 115–121. (in Slovak, English summary)

Zelený J. 1972 – Návrh členení Československa pro faunistický výskum [Proposition of zonation of Czechoslovakia for faunistic research] – Zprávy Čsl. spol. entomol. Praha, 8 pp. (in Slovak, English summary).

(Received after revising September 2007)