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A comparison of terrestrial isopod communities among different habitat types on Mt. Chelmos (Peloponnisos, Greece)

Spyros SFENTHOURAKIS[1*], Dimitris SKOURAS[1] and Yiannis ANASTASIOU[2]

[1] *Section of Animal Biology, Department of Biology, University of Patras, GR-26500 Patras, Greece*
[2] *Section of Zoology and Marine Biology, Department of Biology, University of Athens, GR-15784 Zografou, Greece*

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The mountainous communities of terrestrial isopods (Crustacea, Oniscidea) have not been extensively studied so far, even though they can offer important insights to the structuring of isopod diversity, to the role of these animals on mountainous ecosystems and to altitudinal gradients of diversity. In this work we present the results obtained from the Mt. Chelmos lying at the northern part of the Peloponnisos peninsula (southern continental Greece). Eight habitat types exploited by isopods on this mountain, namely highland meadows ('alpine' ecosystems), highland *Astragalus* formations, hawthorn formations, fir forest, pine forest, mixed coniferous forest, dense maquis and sparse maquis, were studied using pitfall traps emptied at a monthly basis for seven months. All sampling sites were located at elevation from 800 to 2100 m a.s.l. Species richness recorded in pitfall traps is low (nine species) and is not correlated with elevation. Abundance is highest in highland hawthorn formations. Summer months showed the higher abundances. One species of the genus *Armadillidium* (*A. tripolitzense*) dominates communities of higher elevations, as also found in other Greek mountains. Habitats are clustered according to elevation, forming three groups with similar isopod communities, namely sites above the forest line, fir and mixed coniferous forests, and maquis with pine forest that occur at lower elevations. A comparison with known data for isopods from other Greek mountains is also provided.

Key words: mountainous communities, isopods, diversity, elevational gradient, community structure.

INTRODUCTION

Mountainous biota are important elements of global biodiversity, as they exhibit increased levels of endemism and offer very useful natural experiments for the study of ecological, physiological and biogeographic patterns (Körner & Spehn, 2002; Nagy *et al.*, 2003). Nevertheless, only few studies of mountainous oniscidean (Crustacea, Isopoda, Oniscidea) communities have been published so far (Schmalfuss & Ferrara, 1982; Sfenthourakis, 1992; Beron, 1997; Lymberakis *et al.*, 2003; Lopes *et al.*, 2005; Sfenthourakis *et al.*, 2005). In the recent past, research has been conducted on the terrestrial isopods of several Greek mountains (Lymberakis *et al.*, 2003; Sfenthourakis *et al.*, 2005). In the present paper, we present a study of the isopod communities in different habitat types on one additional Greek mountain, Mt. Chelmos (north Peloponnisos peninsula), spanning at a broad elevational range. Taking into account that we still lack an adequate picture of isopod mountainous communities in Greece, but also at a global scale, the aim of this study is to describe and compare the isopod communities among habitat types and elevations on this mountain, and to evaluate these findings with published data from other Greek mountains. The isopod fauna of Mt. Chelmos is more or less known from various sparse records of species, but no study has focused on its community structure. A total of 13 species have been reported from Mt. Chelmos (Schmalfuss, 2003, 2006; Klossa-Kilia *et al.*, 2006), eight of which are endemic to Greece (four endemic to Pelo-

* Corresponding author: tel.: +357 22893998, fax: +357 22895331, e-mail: sfendour@ucy.ac.cy, sfendo@upatras.gr, current address: Department of Biological Sciences, University of Cyprus, PO Box 20537, 1678 Nicosia, Cyprus

ponnisos peninsula). Insights into mountainous communities of invertebrate groups such as isopods that are particularly sensitive to humidity and temperature, may also prove crucial for understanding the dynamics of climate change. In this perspective, we also aim to explore the role of the forest line on isopod communities, given that the forest line is expected to move higher in response to global warming, and since previous studies have shown quite different communities and/or patterns above and below the forest line (Schmalfuss & Ferrara, 1982; Lymberakis *et al*., 2003; Sfenthourakis *et al*., 2005). Also, previous studies have reported either a negative effect of elevation on oniscidean species richness (Sfenthourakis, 1992; Lymberakis *et al*., 2003) or no such effect (Sfenthourakis *et al*., 2005) on different mountains. Another interesting pattern reported from all Greek mountains studied so far is the very high abundance of one species on higher elevations, usually a member of the genus *Armadillidium*. The types of habitat present on most mountains of Greece show some consistency, with evergreen sclerophyllous scrubs at lower elevations, forests at mid-elevations, to a large extent consisting of coniferous trees, open hawthorn woodland near the treeline and subalpine meadows, usually with *Astragalus* spp., at higher sites. Irrespective of elevational richness gradients, higher abundances have been found in the more elevated open habitats, mainly due to the afore-mentioned population 'explosion' of one species (Sfenthourakis, 1992; Lymberakis *et al*., 2003). In view of these findings, it is worth-examining if similar patterns are exhibited by onicidean communities of Mt. Chelmos too.

MATERIALS AND METHODS

Study sites

Mt. Chelmos is a calcareous mass lying at the north-central part of Peloponnisos peninsula, reaching a maximum elevation of 2355 m a.s.l. A large part has been included in the NATURA 2000 network (GR2320002, Dafis *et al*., 1996). There are extensive coniferous forests, mainly of the Greek endemic fir species *Abies cephalonica*, but also of pines (*Pinus nigra*) at medium elevations. Maquis formations are present at lower sites, mainly with *Quercus coccifera,* in deforested places reaching 1000 m. At 1600-1900 m there are sparse hawthorn patches mixed with meadows, mainly *Astragalus* formations, which is the habitat type extending untill the peak. Deciduous forests are lacking, except for stands with plane trees around the numerous streams and rivers that spring from the slopes.

Sampling

Monthly sampling was performed for seven consecutive months (May to November 2008) in eight sites with the following habitat types: Dense maquis (DM) – 800 m a.s.l. (38°01′33′′N, 22°07′52′′E); Sparse maquis (SM) – 1000 m a.s.l. (38°00′19′′N, 22°08′01′′E); Pine forest (PF) – 1100 m a.s.l. (38°00′01′′N, 22°13′55′′E); Fir forest (FF) – 1200 m a.s.l. (37°51′46′′N, 22°14′03′′E); Mixed coniferous forest (MF) – 1200 m a.s.l. (37°59′45′′N, 22°13′59′′E); Highland hawthorn woodland (CF) – 1700 m a.s.l. (38°00′42′′N, 22°12′15′′E); Highland *Astragalus* formations (AF) – 1700 m a.s.l. (38°00′51′′N, 22°12′25′′E); Subalpine meadow (AM) – 2100 m a.s.l. (37°59′48′′N, 22°11′19′′E). One transect with ten pitfall traps, without replicates, was placed in each sampling location (site). Traps consisted of plastic cups (7 cm diameter, 10 cm depth) filled to 1/3 with ethylene-glucole. The traps were placed in a straight line, at a distance of 5 m between each other, and were emptied monthly. Isopods were identified at species level and counted. All values were transformed to 100 trap-days before analyzed further.

Data analysis

Spearman's rank correlation coefficient was used for testing the correlation between elevation and species richness. Comparisons of isopod abundances among habitat types (sites) and months were performed using one-way ANOVA, since the lack of replicate trap transects did not permit the use of two-way ANOVA. In the analysis of sites, months were used as replicates, while sites were used as replicates in the analysis of months. Similarities among sampling stations were explored using the Bray-Curtis index and the UPGMA clustering technique. Shannon diversity (H′) and Pielou's equitability (J′) indices, as well as Fisher's α, an index of diversity that is independent of sample size, were calculated for each habitat type.

RESULTS

A total of 5378 individuals representing nine species were collected (Table 1), two of which had not been previously reported from this mountain, while six species mentioned in literature were not found. The total number of species found per sampling site ranged

TABLE 1. Isopod species collected in pitfall traps and reported in literature from Chelmos mountain

Species	Collected	Reported	References
Ligidium beieri Strouhal, 1928	+	+	Klossa-Kilia *et al*. (2006)
Ligidium sp.		+	Klossa-Kilia *et al*. (2006)
Hyloniscus beckeri Herold, 1959		+	Schmalfuss (1979)
Chaetophiloscia cellaria (Dollfus, 1884)	+		
Philoscia univittata Strouhal, 1937		+	Schmalfuss (1990)
Orthometopon dalmatinum (Verhoeff, 1901)	+	+	Schmalfuss (1979)
Trachelipus kytherensis (Strouhal, 1929)*	+	+	Parmakelis *et al*. (2008)
Porcellio nasutus Strouhal, 1936	+	+	Schmalfuss (1979)
P. peloponnesius Strouhal, 1936	+	+	Schmalfuss (1979)
Porcellionides myrmecophilus (Stein, 1859)		+	Schmalfuss (1979)
P. pruinosus (Brandt, 1833)	+	+	Schmalfuss (1979)
Armadillidium humectum Strouhal, 1937	+		
A. kuehnelti Schmalfuss, 2006		+	Schmalfuss (2006)
A. peloponnesiacum Verhoeff, 1901		+	Schmalfuss (2006)
A. tripolitzense Verhoeff, 1902	+	+	Schmalfuss (2006)

*According to Parmakelis *et al*. (2008) its taxonomy should be revised

TABLE 2. Species richness (S), mean abundance (A, individuals per 100 trap-days), month of higher abundance with respective value (MHA), Pielou's equitability index (J′), Shannon-Wiener diversity index (H′) and Fisher's α for the eight habitat types (see Methods for abbreviations) studied on Mt. Chelmos

	S	A	MHA	J′	H′ ($\log_e$)	Fisher's α
DM	4	47.588	July (19.853)	0.636	0.882	1.040
SM	2	40.060	July (12.500)	0.329	0.228	0.443
PF	4	127.190	August (40.811)	0.155	0.215	0.785
FF	3	18.365	June (11.842)	0.762	0.837	2.585
MF	4	5.666	November (2.222)	0.708	0.981	1.576
AF	3	310.990	August (126.641)	0.464	0.510	0.460
CF	4	637.354	July (216.609)	0.041	0.057	0.570
AM	2	273.669	June (98.888)	0.156	0.108	0.292

TABLE 3. Results of one-way ANOVA of isopod abundances among different sites (using months as replicates) and between months (using sites as replicates); SS = sum of squares; df = degrees of freedom; MS = mean square

		SS	df	MS	F	*p*
Sites	Between groups	47541.9	7	6791.7	4.69	0.0005
	Within groups	69573.8	48	1449.4		
Months	Between groups	20202.2	6	3367.0	1.70	0.1404
	Within groups	96913.5	49	1977.8		
Total		117116.0	55			

between two (SM and AM) and four (DM, PF, MF, CF), while the total number of species per month ranged from five in November, six in May, June, August and September, seven in July and eight in October. Maximum total abundance was found in CF (Fig. 1) and in July (Table 2).

No correlation of species richness with elevation was found (Spearman r = -0.37, $p > 0.05$; Spearman r = -0.29, $p > 0.05$).

Maximum diversity according to H′ index was found in MF and DM, and minimum in CF (Table 2). Nevertheless, equitability varied from relatively high

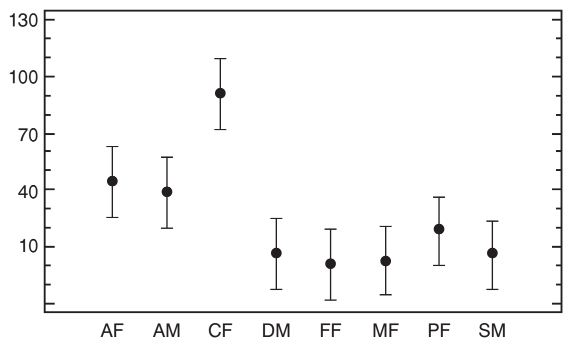

FIG. 1. Mean values (with standard error bars) of captured isopods (individuals per 100 trap-days) in each habitat type studied (pooled monthly values). Abbreviations: DM, dense maquis; SM, sparse maquis; PF, pine forest; FF, fir forest; MF, mixed coniferous forest; CF, highland hawthorn woodland; AF, highland *Astragalus* formations; AM, subalpine meadow.

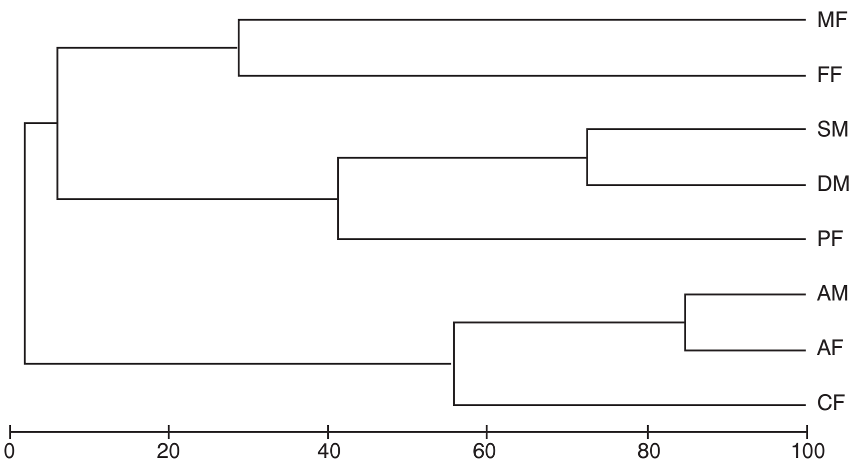

FIG. 2. Clustering of habitat types studied herein, using the UPGMA method and the Bray-Curtis similarity index. Abbreviations as in Fig. 1.

in FF, MF and DM to very low in CF due to the extreme abundance of one species (*A. tripolitzense*), so these diversity values are not directly comparable among sites. According to Fisher's α, that is less sensitive to sample size, FF and AM exhibited highest and lowest diversity, respectively (Table 2).

Abundances of isopods differed significantly only among sites (Table 3). Bonferroni post-hoc test identified three homogeneous groups of sites corresponding to open sites above the forest line (AF, AM), hawthorn formations (CF), and forested sites below the forest line (DM, SM, PF, FF, MF).

Clustering of sites (Fig. 2) revealed three groups, those above the forest line (AF, CF, AM), the fir forest with the mixed forest (FF, MF), and the three lower sites with maquis and pine forest (DM, SM, PF). The latter two form a larger group. Inside each group, sites of similar vegetation cover are closer to one-another (DM-SM and AM-AF).

DISCUSSION

The results of this study revealed patterns that are markedly similar to those reported from other Greek mountains (Sfenthourakis, 1992; Lymberakis *et al*., 2003; Sfenthourakis *et al*., 2005). There is one species of the genus *Armadillidium* that reaches very high abundance on sites at high elevations, above the forest line, while the isopod communities of lower forested sites show decreased densities, even though species richness is more or less similar among sites. A reduction of species richness with elevation found in most other mountains of Greece, except the nearby Mt. Panachaiko (Sfenthourakis, 1992; Lymberakis *et al*., 2003; Sfenthourakis *et al*., 2005), could not be detected for Mt. Chelmos, but this may be due to the small total number of species found in pitfall traps. It is possible that when other species, [such as those living in ant nests (e.g. *Platyarthrus* spp. and *Porcellionides myrmecophilus*) or in strictly riparian habitats (e.g.

Hyloniscus beckeri, Ligidium sp., *Philoscia univittata*)] are to be taken into account, a significant trend could have been observed, since these species are restricted in low to middle elevations and are absent above the forest line.

From the six species reported in literature but not found during this study, *Ligidium* sp. is present only at riparian sites on the southern slopes of the mountain, while *Porcellionides myrmecophilus* inhabits ant nests, so usually does not fall into pitfall traps. The absence of *Hyloniscus beckeri* and *Philoscia univittata* from the samples is probably due to the special habitat preferences of these species that exploit very humid sites near springs or stream and river banks. There is some ambiguity on the diagnosis of *Armadillidium kuehnelti* in relation to *A. humectum*, and possibly there are intermediate forms between these two 'species'. The material captured in pitfall traps conforms perfectly to the diagnosis of *A. humectum* given by Schmalfuss (2006) who reports the species from south Peloponnisos and not from Mt. Chelmos, where *A. kuehnelti* is supposed to be present. Further work is needed for the clarification of taxonomic and differentiation patterns inside this genus. Finally, *Armadillidium peloponnesiacum* has been found in lower sites, so it is probably lacking from the study area.

The importance of hawthorn stands for mountainous isopod communities, as previously observed on Mt. Panachaiko (Sfenthourakis *et al*., 2005), is corroborated, since this habitat type hosts the highest abundance and the highest species richness, the latter shared with dense maquis formations. On Mt. Panachaiko, hawthorn and maquis formations exhibited the highest diversities (Sfenthourakis *et al*., 2005), whereas in this study the highest diversity values were found on fir and mixed coniferous forest, an artifact produced by the very low equitability of richer communities.

The isopod communities of Mt. Chelmos, even though they do not exhibit a clear elevational gradient in richness or abundance, do show an elevational structure as far as their composition is concerned, as shown by cluster analysis as well as by the distinctive abundance and diversity patterns above and below the forest line. It is clear that habitats above the forest line offer very favorable conditions for certain species that reach extremely high abundances. This could be attributed to a reduction of predation stress in combination with physiological adaptations of species belonging to a clade (the monophyletic genus *Armadillidium*) presumably differentiated during periods of cold climate. Such a hypothesis has to be tested through phylogenetic and ecophysiological studies, but there is strong positive evidence from distributional and populational data from other Greek mountains. Even on the isolated island of Crete, the most abundant species present only on subalpine habitats of Mt. Lefka Ori is a member of the same genus (Lymberakis *et al.*, 2003; Schmalfuss *et al*., 2004).

Abundance values on Mt. Chelmos were strikingly higher than those on Mt. Panachaiko in most habitat types (Sfenthourakis *et al*., 2005 - when values are rescaled to equal numbers of trap per days). Total abundance was highest in hawthorn formations, while highland meadows hosted the highest abundance on Mt. Panachaiko. Such differences might reflect different responses of the different species constituting the main bulk of isopod communities in the two mountains, or possible habitat quality differences between these mountains. Mt. Chelmos consists mainly of calcareous substrate while Mt. Panachaiko of flysch, and soil erosion and degradation of vegetation are far more obvious on the latter, factors that probably lead to the overall higher abundances of isopods on Mt. Chelmos. On the other hand, the main part of the highland meadows on Mt. Panachaiko is located on a protected plateau that receives a lot of freshwater from the surrounding peaks. These peaks also reduce the harsh effects of strong winds, while the respective meadows on Mt. Chelmos are exposed to winds and are relatively less humid, so that this habitat type is less favorable of the latter.

A comparison of isopod distribution on six Greek mountains studied so far (Table 4) shows that the forest line seems to be an important threshold for isopods only on mountains lying at the southernmost parts of Greece (Taygetos and Lefka Ori), probably reflecting the increased harshness of conditions on treeless sites during summer for such hygrophilous organisms. Also, on the northernmost and higher mountains (Chelmos, Tymfi, Olympos) there are no species distributed at all elevations. In any case, though, the most striking pattern on all six mountains is the dominance (extreme in most cases) of one species near the top. On all mountains of the external Hellenides (Doutsos *et al*., 2006) this species belongs to the same genus (*Armadillidium*) whereas on Mt. Olympos, a mountain that has a separate orogenetic history and is relatively isolated from the others, this species belongs to a different genus (*Porcellium*) that is generally lacking from the Pindos mountain range, even though it as widely distributed in Europe and

TABLE 4. A comparison of data on isopods from six Greek mountains. Sources: Chelmos, current study; Panachaiko, Sfenthourakis *et al.* (2005); Taygetos, Tymfi and Olympos, Sfenthourakis (1992); Lefka Ori, Lymberakis *et al.* (2003)

	Chelmos	Panachaiko	Taygetos	Tymfi	Olympos	Lefka Ori
Maximum altitude (m)	2355	1924	2407	2438	2917	2453
Elevational richness gradient	no	no	yes	yes	yes	yes
Elevational abundance gradient	no	no	?	?	?	yes
Abrupt richness drop at treeline	no	no	yes	no	no	yes
Dominance of one species at alpine habitats	yes (*Armadillidium tripolitzense*)	yes (*A. lobocurvum* Verhoeff, 1902)	yes (*A. tripolitzense*)	yes (*A.* sp. aff. *irmengardis*)	yes (*Porcellium recurvatum* Verhoeff, 1901*)	yes (*A. lymberakisi* Schmalfuss, Paragamian & Sfenthourakis, 2004)
Appearance of new species at higher sites	no	no	no	no	no	yes
Species spanning all elevations	0	4	2	0	0	1

* Reported as *P. storkani* Frankenberger, 1940 in Sfenthourakis (1992)

the Balkans (Schmalfuss, 2003). The possibility of competition effects between species of these two genera should be further explored.

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REFERENCES

Beron P, 1997. On the high mountain Isopoda Oniscidea in the Old World. *Historia Naturalis Bulgarica*, 8: 85-100.

Dafis S, Papastergiadou E, Georghiou K, Babalonas D, Georgiadis T, Papageorgiou M, Lazaridou M, Tsiaousi V, 1996. *Directive 92/43/EEC The Greek "Habitat" Project NATURE 2000: An Overview. Life Contract B4-3200/94/756, Commission of the European Communities DG XI*. The Goulandris Natural History Museum, Greek Biotope/Wetland Centre, Athens.

Doutsos T, Koukouvelas IK, Xypolias P, 2006. A new orogenic model for the External Hellenides. *Geological Society, London, Special Publications*, 260: 507-520.

Klossa-Kilia E, Kilias G, Tryfonopoulos G, Koukou K, Sfenthourakis S, Parmakelis A, 2006. Molecular phylogeny of the Greek populations of the genus *Ligidium* (Isopoda, Oniscidea) using three mtDNA gene segments. *Zoologica Scripta*, 35: 459-472.

Körner C, Spehn EM, 2002. *Mountain biodiversity. A global assessment.* Parthenon, London.

Lopes ERC, Mendonça MSJr, Bond-Buckup G, Araujo PB, 2005. Oniscidea diversity across three environments in an altitudinal gradient in northeastern Rio Grande do Sul, Brazil. *European Journal of Soil Biology*, 41: 99-107.

Lymberakis P, Mylonas M, Sfenthourakis S, 2003. Altitudinal variation of oniscidean communities on Cretan mountains. In: Sfenthourakis S, Araujo PB, Hornung E, Schmalfuss H, Taiti S, Szlavecz K, eds. *The Biology of Terrestrial Isopods V. Crustaceana Monographs*, 2: 217-230.

Nagy L, Grabherr G, Körner C, Thompson DBA, 2003. *Alpine biodiversity in Europe*. *Ecological Studies 167*. Springer-Verlag, Berlin, Heidelberg.

Parmakelis A, Klossa-Kilia E, Kilias G, Triantis KA, Sfenthourakis S, 2008. Increased molecular divergence of two endemic *Trachelipus* (Isopoda, Oniscidea) species from Greece reveals patterns not congruent with current taxonomy. *Biological Journal of the Linnean Society*, 96: 361-370.

Schmalfuss H, 1979. Revidierte Check-list der Landisopoden Griechenlands. *Stuttgarter Beiträge zur Naturkunde*, *Ser. A*, 331: 1-42.

Schmalfuss H, 1990. Die Land-Isopoden (Oniscidea) Griechenlands. 12. Beitrag: Gattungen *Lepidoniscus* und *Philoscia* (Philosciidae). *Stuttgarter Beiträge zur Naturkunde*, *Ser. A*, 448: 1-11.

Schmalfuss H, 2003. World catalog of terrestrial isopods (Isopoda: Oniscidea). *Stuttgarter Beiträge zur Naturkunde*, *Ser. A*, 564: 1-341.

Schmalfuss H, 2006. The terrestrial isopods (Isopoda: Oniscidea) of Greece. 23rd contribution: The genus *Armadillidium* (Armadillidiidae) on the Peloponnese. *Stuttgarter Beiträge zur Naturkunde*, *Ser. A*, 693: 1-102.

Schmalfuss F, Ferrara F, 1982. Observations on the distribution and ecology of terrestrial isopods (Oniscoidea) in south-west Cameroon. *Monitore Zoologico Italiano*, 10: 243-265.

Schmalfuss S, Paragamian K, Sfenthourakis S, 2004. The terrestrial isopods (Isopoda: Oniscidea) of Crete and the surrounding islands. *Stuttgarter Beiträge zur Naturkunde*, *Ser.* A, 662: 1-74.

Sfenthourakis S, 1992. Altitudinal effects on species richness of Oniscidea (Crustacea; Isopoda) of three mountains in Greece. *Global Ecology and Biogeography Letters*, 2: 157-164.

Sfenthourakis S, Anastasiou I, Strutenschi T, 2005. The terrestrial isopod diversity of Mt. Panachaiko (Peloponnisos, Greece). *European Journal of Soil Biology*, 41: 91-98.