

BIODIVERSITY INTERSLOPE DIVERGENCE
OF ORIBATID MITES AT “EVOLUTION CANYON”,
MOUNT CARMEL, ISRAEL¹

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We studied the local distribution of oribatid mites at “Evolution Canyon”, lower Nahal Oren, Mt. Carmel, Israel. Altogether, 135 species of oribatid mites from 54 families and 88 genera were collected in two years. Species richness and abundance were significantly lower on the “African-savannoid”-like south-facing slope than on the more humid, cooler, “European” north-facing slope covered by a dense Mediterranean garrigue and were positively correlated. The majority of species were widely distributed, *i.e.*, cosmopolitan, Holarctic, Palaearctic, and Euro-East Mediterranean. A similarity of the mites’ interslope differentiation pattern to the “water-dependent” groups, such as Collembola, mosses, and fungi, indicates that water availability might be the most important underlying differentiating slope factor in spite of the fact that mite species richness increased upslope and water increased downslope on both slopes. This conclusion supports the idea that water, energy, and water-energy balance might be good predictors for local as well as global distribution patterns of species richness in many organismal groups.

Key words: Oribatida, mites, species richness, Israel

INTRODUCTION

Free-living Oribatida is a species-rich group of small heavily sclerotised mites that are important agents in soil energetics and soil fertility because their abundance might reach tens of thousands of specimens per square meter of soil (SEYD & SEAWARD 1984). Usually, they feed on partly exploited vegetable or animal matter and on saprophytic, arbuscular mycorrhizal and ectomycorrhizal fungi (SCHNEIDER *et al.* 2005). They are K-selected organisms since their development time is long, lasting from several months to two years in temperate forests (LUXTON 1981); they are characterized by low fecundity and low metabolic rates. Apart from sexual reproduction, thelytokous parthenogenesis is often present

1 DEDICATION: This paper is dedicated to the brilliant and prominent Hungarian soil biologist and acarologist Dr SÁNDOR MAHUNKA on the occasion of his 70th birthday. *Felix dies natalis!*

(NORTON *et al.* 1993). About 9,000 species of oribatid mites are described worldwide (SUBIAS 2004), but this represents only a very small fraction of their actual species richness. Unfortunately, the pattern of global species richness distribution in oribatid mites is not well known.

Our study on oribatid mites living in soil and litter was done at the microsite "Evolution Canyon" ("EC") where already a large number of studies devoted to the problems of biodiversity evolution and dynamics have been conducted (reviewed in NEVO 1995, 1997, 2001). As a consequence, we were able to compare our results obtained on oribatid mites with the results obtained on other taxa across life at the same microsite.

MATERIALS AND METHODS

Description of the microsite

The "Evolution Canyon" ("EC") microsite (32°43'N 34°58'E) is located at lower Nahal Oren, Mt. Carmel, Israel. The "EC" is of a Plio-Pleistocene origin, presumably 3–5 million years old (NEVO 1995), and it runs across Mt. Carmel in an east-west direction to the Mediterranean Sea. Opposite south-facing and north-facing slopes are separated by a distance of 100 m at the valley bottom and 400 m at the valley top. The xeric "African" (AS) south-facing slope is covered by an open park forest of evergreen *Ceratonia siliqua*-*Pistacia lentiscus*, with dominant savanna-like grassland. By contrast, the mesic "European" (ES) north-facing slope is covered by a dense Mediterranean garrigue of abundant evergreen *Quercus calliprinos* and deciduous *Pistacia palaestina* (NEVO *et al.* 1999). Shared characteristics of both slopes are (1) evolutionary history, (2) geology (Upper Cenomanian Limestone (KARCZ 1959)), (3) regional Mediterranean climate (mean annual rainfall ca. 600 mm, potential evapotranspiration 1700 mm, and mean temperatures of 13 °C in January and 28 °C in August, respectively (Atlas of Israel 1970)), and (4) pedology (terra rossa on both slopes, NEVO *et al.* 1998). Due to differences in geographic orientation, the AS receives significantly higher insolation, and, consequently, it is warmer, less humid, and with larger microclimate differences between day and night than the opposite ES (PAVLÍČEK *et al.* 2003). Notably, water availability increases downslope due to water runoff and deeper soil profiles at the bottom (NEVO *et al.* 1998).

Collection and fixation of mites

This study of oribatid mites included several stages: sampling, isolation of mites, fixation, identification, and statistical analyses. Samples were collected at seven stations. There were three stations on each slope at 60, 90, and 120 m above sea level; stations were numbered AS1, AS2, and AS3 on the AS from top to bottom, and stations were numbered ES5, ES6, and ES7 on the ES from bottom to top, while station VB4 was located at the valley bottom. At each station sampling was conducted horizontally across 100 m.

A total of 84 soil samples (upper layer of the soil up to depth of a 5 cm, approximately 100 grams) and detritus were collected in 1999. Five samples were collected by a small shovel from each station in February and August, 1999, and two samples from each station in April, 1999. The exact

amount of the soil sample was adjusted in the laboratory to 100 grams. The collection was repeated in April, 2005, but the 69 samples 10×10×10 cm were cut out by a sharp knife. Ten samples were collected on each station but only nine samples on the VB. Immediately after collection, samples were always sent via air mail to the laboratory at the State Museum in Lviv, where mites were isolated using the modified Berlese-Tulgren funnels. The mites were separated from the substrate using a dense net in a funnel containing 50–70% alcohol. This method is based on a common feature of soil animals, namely, positive hydrotaxis. Collection and counting of testaceous mites in filtrated samples were carried out under a binocular microscope using preparation needles. Collected mites were fixed in Fora-Berlese liquid on microscope slides covered by cover slips, both degreased by 96.6% alcohol. Permanent slides were kept in 40–60 °C for 3–4 days. Alternatively, mites were fixed and stored in glass jars with an alcohol-glycerol mixture (10:1) (GILYAROV & KRIVOLUTSKY 1975, KRIVOLUTSKY *et al.* 1995).

Identification of mites

Observations and identification of oribatid mites were carried out using Amplival and Enoval microscopes. The following taxonomic literature was used for mite identification (GILYAROV & KRIVOLUTSKY 1975, BALOGH & MAHUNKA 1983, SUBIAS & BALOGH 1989, and BALOGH & BALOGH 1992).

Statistics

Since data were not parametric, we used the factor analysis based on the Spearman correlation matrix to estimate the number of factors needed to explain inter-station variability in species richness. To test the significance of the interslope differences we used the following model (abbreviated Interslope Difference or “ID” model) based on the Median test: According to this model, the interslope difference is significant ($p = 0.05$) if the species richness of any group is higher on three stations of the one slope than the species richness of the same group on the three stations of the opposite slope. The same applies to the interslope comparisons of abundance on the species level. We did not consider the rank of stations on the same slope because we had no prediction for it. This procedure is rather conservative (*i.e.*, in comparison with the Binomial test) but, in our opinion, more realistic because, at least somewhat, it eliminates collection bias due to the different sampling methodologies in each sampling year. In a few cases, we used the Binomial test (<http://home.clara.net/sisa/binomial.htm>) and other tests included in Statistica for Windows (Version 6, StatSoft Inc.) and EstimateS (Version 8.0, COLWELL 2005).

RESULTS

Species richness and abundance

One hundred and thirty-five species of oribatid mites were collected at “EC” (Table 1) in two years. They belonged to 54 families and 88 genera (*ibid.*). The most speciose families were Oppiidae (18 species) and Phthiracaridae (seven species). Only one species was presented in 29 families (*ibid.*) and families Lohmanniidae, Camisiidae, Hermanniidae, Gustaviidae and Autognetidae were repre-

sented by one collected specimen only. Out of all collected species 130 were collected on slopes and 41 at the VB4 (ibid.). However, we did not pay much attention to the analysis of the VB4 data because our target was to study the interslope differences.

In two years, 60 species were collected at the AS and 111 species at the ES and the ES stations were well separated from the AS stations by a tree diagram using the hierarchical clustering Ward method (WARD 1963) based on the Sørensen index of community similarity (in COLWELL 2005), which accounts for the abundance of individual species (Fig. 1). The number of mite species was significantly lower on the AS than on the ES according to the ID model (Table 1). It was also significantly lower, when comparing the 70 species missing on the AS with the 19 species missing on the ES (Binomial test, two-sided test, expected proportion = 0.5, $p < 0.001$). The significant interslope trends in the same direction were obtained in each year separately.

According to the ID model 23 species were significantly more abundant at the ES and only two species were significantly more abundant at the AS (interslope difference was $p < 0.001$, Binomial test). The total abundance has been higher on the ES than on the AS every year according to the ID model. The abundance increased upslope on the AS but not on the ES (Table 1) and was significantly and positively correlated with species richness (Spearman $R = 0.893$, $p = 0.007$). However, the Shannon diversity index (representing a mean of 50 runs) showed the increased ecological diversity from AS1 to ES7; in other words, it showed higher diversity at the ES than at the AS, but it did not support the upslope increase of diversity on the AS. The values of the Shannon index were as follows: AS1 = 3.19; AS2 = 3.62; AS3 = 3.80, VB4 = 3.91; ES5 = 3.96; ES6 = 4; and ES7 = 4.03. The same station orders were obtained by the abundance based coverage estimator and by the Simpson index (for details about indices, see COLWELL 2005).

Interslope distribution of mites and other phylogenetic groups

Factor analysis using the Spearman correlation matrix (based on ranking their species richness according to stations) of the groups listed in Table 2 indicates that mites are classified together with groups more speciose on the ES such as Collembola, soil fungi, Basidiomycetes, Bryophyta, and trees and shrubs (positive factor 1) and in the opposite direction of groups more speciose on the AS such as Rhopalocera, reptiles, darkling beetles, Dermestidae, Histeridae, and Orthoptera (negative factor 1 in Fig. 2). Factor 1 (eigenvalue = 9.48) could explain 79% of variance. Factor 2 (eigenvalue = 1.32) can explain 11% of the variance and, if positive, shows that species richness increases from the lower parts of slopes to the up-

Table 1. Oribatid mite species collected at "EC" and their abundance according to stations and year of collection. Marked in bold is the abundance of species showing significant interslope differences according to the ID model. The taxonomic system follows BALOGH and BALOGH (1992).

Family, species	99/05	AS1	AS2	AS3	VB	ES5	ES6	ES7
CTENACARIDAE								
<i>Ctenacarus araneola</i> (GRANDJEAN, 1932)	+/-	0/0	10/0	0/0	0/0	0/0	0/0	5/0
ENIOCHTHONIIDAE								
<i>Eniochthonius minutissimus</i> (BERLESE, 1903)	-/+	0/0	0/0	0/0	0/0	0/3	0/0	0/0
HYPOCHTHONIIDAE								
<i>Hypochthonius rufulus</i> C. L. KOCH, 1835	-/+	0/0	0/0	0/0	0/0	0/0	0/0	0/2
COSMOCHTHONIIDAE								
<i>Cosmochthonius</i> sp.1	+/+	0/0	16/1	0/1	0/2	0/0	0/10	1/0
<i>Cosmochthonius</i> sp.2	+/+	1/0	0/1	0/0	1/0	0/1	0/0	0/0
PROTOPLOPHORIDAE								
<i>Cryptoplophora abscondita</i> GRANDJEAN, 1932	+/+	1/0	0/0	1/0	0/0	0/1	0/96	2/8
<i>Cryptoplophora</i> sp.	-/+	0/0	0/0	0/0	0/4	0/2	0/0	0/0
SPHAEROCHTHONIIDAE								
<i>Sphaerochthonius splendidus</i> (BERLESE, 1904)	+/+	4/3	5/0	3/0	0/3	0/16	2/16	5/53
BRACHYCHTHONIIDAE								
<i>Poecilochthonius italicus</i> (BERLESE, 1910)	-/+	0/0	0/0	0/0	0/0	0/0	0/0	0/4
PHTHIRACARIDAE								
<i>Atropacarus phyllophorus</i> (BERLESE, 1904)	-/+	0/0	0/1	0/0	0/0	0/16	0/16	0/19
<i>Atropacarus platakisi</i> MAHUNKA, 1979	+/+	0/0	0/0	0/0	1/0	13/1	19/0	23/0
<i>Atropacarus striculus</i> (KOCH, 1835)	+/-	0/0	0/0	0/0	0/0	0/0	0/0	1/0
<i>Hoplophthiracarus</i> sp.	+/-	2/0	0/0	2/0	2/0	10/0	1/0	3/0
<i>Phthiracarus piger</i> (SCOPOLI, 1763)	+/+	0/0	0/1	0/0	0/0	6/0	0/0	1/0
<i>Phthiracarus</i> sp.	+/+	0/0	0/0	0/0	0/0	0/4	1/11	0/2
<i>Steganacarus carinatus</i> (C.L. KOCH, 1841)	-/+	0/0	0/0	0/0	0/0	0/6	0/3	0/0
<i>Steganacarus</i> sp.	+/+	0/0	0/0	1/0	0/0	1/1	0/1	0/9
EUPHTHIRACARIDAE								
<i>Euphthiracarus cf. cribrarius</i> (BERLESE, 1904)	+/+	0/0	0/1	0/0	0/0	1/0	0/0	0/0
<i>Rhysotritia duplicata</i> (GRANDJEAN, 1953)	+/-	0/0	0/0	0/0	0/0	1/0	0/0	0/0
LOHMANNIIDAE								
<i>Thamnacarus longisetosus</i> BULANOVA-ZACHVATKINA, 1978	+/-	0/0	1/0	0/0	0/0	0/0	0/0	0/0
EPILOHMANNIIDAE								
<i>Epilohmannia inexpectata</i> SCHUSTER, 1960	+/+	1/0	0/0	1/0	0/0	2/2	2/3	1/1
CAMISIIDAE								
<i>Platynothrus peltifer</i> (C. L. KOCH, 1839)	-/+	0/0	0/1	0/0	0/0	0/0	0/0	0/0

Table 1 (continued)

Family, species	99/05	AS1	AS2	AS3	VB	ES5	ES6	ES7
NOTRIDAE								
<i>Nothrus biciliatus</i> KOCH, 1841	+/-	2/0	0/0	0/0	0/0	0/0	0/0	2/0
MALACONOTHRIDAE								
<i>Malacothrus molliestusus</i> HAMMER, 1952	+/+	1/1	00	0/0	0/0	0/1	1/1	0/2
HERMANNIIDAE								
<i>Hermannia gibba</i> (C. L. KOCH, 1839)	-/+	0/0	0/0	0/0	0/0	0/0	0/1	0/0
HERMANNIELLIDAE								
<i>Hermanniella cf. dolosa</i> GRANDJEAN, 1931	-/+	0/0	0/0	0/0	0/1	0/0	0/0	0/0
<i>Hermanniella granulate</i> (NICOLET, 1855)	-/+	0/0	0/0	0/0	0/0	0/32	0/34	0/8
<i>Hermanniella</i> sp.	+/-	0/0	0/0	0/0	0/0	0/0	2/0	0/0
LIODIDAE								
Genus spp.	-/+	0/1	0/0	0/0	0/0	0/20	0/5	0/6
ALEURODAMAEIDAE								
<i>Aleurodamaeus setosus</i> (BERLESE, 1883)	+/+	0/0	0/0	0/0	0/2	2/6	0/2	1/3
GYMNODAMAEIDAE								
<i>Arthrodamaeus cf. femoratus</i> (KOCH, 1840)	+/+	3/1	1/1	0/0	0/0	0/3	6/6	0/5
Genus spp.1	+/+	0/0	1/3	0/0	1/4	0/0	3/0	0/0
Genus spp.2	-/+	0/0	0/0	0/0	0/6	0/8	0/12	0/10
LICNODAMAEIDAE								
<i>Licnodamaeus</i> sp.	+/+	0/0	0/0	0/0	1/0	0/26	0/2	0/0
PLATEREMAEIDAE								
<i>Lopheremaeus</i> sp.	+/-	3/0	0/0	0/0	0/0	1/0	0/0	5/0
LICNOBELBIDAE								
<i>Licnobelba alestensis</i> GRANDJEAN, 1931	+/+	0/0	0/0	0/0	0/2	0/83	12/81	1/14
DAMAEIDAE								
<i>Belba daghestanica</i> BULANOVA-ZACHVATKINA, 1962	+/+	1/0	0/0	1/0	0/3	1/0	3/3	3/0
<i>Belba minuta</i> BULANOVA-ZACHVATKINA, 1962	+/-	0/0	0/0	0/0	0/0	0/0	0/0	1/0
<i>Belba pseudocorynopus</i> MARKEL, 1960	-/+	0/0	0/1	0/0	0/0	0/0	0/3	0/5
<i>Metabelba pulverulenta</i> (C. L. KOCH, 1839)	-/+	0/0	0/0	0/0	0/0	0/1	0/0	0/0
CEPHEIDAE								
<i>Oribatodes heterosetosus</i> SITNIKOVA, 1975	+/+	0/0	0/0	0/0	0/0	0/0	0/1	1/7
MICROZETIDAE								
<i>Microzetes auxiliaris</i> GRANDJEAN, 1936	+/-	0/0	0/0	0/0	0/0	0/0	3/0	0/0
<i>Nellacarus</i> sp.	-/+	0/0	0/0	0/0	0/0	0/0	0/0	0/2
CTENOBELBIDAE								
<i>Ctenobelba pectinigera</i> (BERLESE, 1908)	+/-	1/0	0/0	0/0	0/0	0/0	0/0	1/0

Table 1 (continued)

Family, species	99/05	AS1	AS2	AS3	VB	ES5	ES6	ES7
DAMAEOLIDAE								
<i>Damaeolus asperatus</i> (BERLESE, 1904)	+/+	0/0	0/0	0/0	0/0	6/2	0/0	5/1
ZETORCHESTIDAE								
<i>Microzetorchestes emeryi</i> (COGGI, 1898)	+/+	0/1	2/4	1/1	0/0	0/1	0/32	0/0
<i>Zetorchestes micronychus</i> (BERLESE, 1883)	-/+	0/0	0/0	0/0	0/0	0/1	0/3	0/0
Genera sp.	+/-	1/0	0/0	0/0	0/0	0/0	0/0	0/0
GUSTAVIIDAE								
<i>Gustavia cf. major</i> (BERLESE, 1904)	-/+	0/0	0/1	0/0	0/0	0/0	0/0	0/0
LIACARIDAE								
<i>Liacarus cf. coranicus</i> (C. L. KOCH, 1840)	-/+	0/0	0/0	0/0	0/0	0/2	0/0	0/1
<i>Liacarus cf. vombi</i> DALENIUS, 1950	+/+	0/0	0/0	0/0	0/0	0/0	0/0	2/1
<i>Liacarus lencoranicus</i> KRIVOLUTSKY, 1967	+/-	0/0	0/0	0/0	0/0	1/0	0/0	0/0
TENUIALIDAE								
<i>Hafenrefferiella hyrcanica</i> D. KRIVOLUTSKY, 1966	-/+	0/0	0/0	0/0	0/0	0/1	0/1	0/1
XENILLIDAE								
<i>Xenillus tegeocranus</i> (HERMANN, 1804)	+/+	1/2	0/0	0/0	0/0	2/5	2/2	1/2
CARABODIDAE								
<i>Austrocarabodes ensifer</i> (SELLNICK, 1931)	+/+	7/0	0/0	0/2	1/1	11/0	0/0	8/0
<i>Carabodes coriaceus</i> KOCH, 1935	+/-	0/0	0/0	0/0	0/0	0/0	2/0	0/0
<i>Carabodes femoralis</i> (NICOLET, 1855)	+/-	0/0	3/0	0/0	0/0	0/0	0/0	0/0
<i>Carabodes labyrinthicus</i> (MICHAEL, 1879)	+/-	0/0	1/0	0/0	0/0	0/0	0/0	0/0
<i>Carabodes marginatus</i> (MICHAEL, 1884)	+/-	0/0	0/0	0/0	0/0	4/0	0/0	0/0
TECTOCEPHEIDAE								
<i>Tectocephus velatus</i> (MICHAEL, 1880)	+/+	2/0	0/1	0/5	1/2	8/0	5/0	6/0
AUTOGNETIDAE								
<i>Conchogneta delacarlica</i> (FORSSLUND, 1947)	+/-	0/0	0/0	0/0	0/0	0/0	0/0	1/0
OPPIIDAE								
<i>Berniniella cf. serratirostris</i> GOLOSOVA, 1970	+/-	0/0	0/0	2/0	0/0	2/0	0/0	0/0
<i>Berniniella bicarinata</i> (PAOLI, 1908)	-/+	0/0	0/0	0/0	0/0	0/0	0/0	0/4
<i>Graptoppia</i> sp.	+/-	0/0	0/0	0/0	0/0	0/0	1/0	0/0
<i>Lauropoppia cf. maritime</i> WILLMANN, 1939	+/+	0/0	1/0	0/0	0/0	0/0	1/3	0/0
<i>Lauropoppia cf. neerlandica</i> (OUDEMANS, 1900)	+/+	0/0	0/0	0/0	0/0	6/13	0/6	0/10
<i>Medioppia globosa</i> (MIHELICIC, 1956)	+/+	0/0	0/0	0/0	1/0	0/1	3/0	4/0
<i>Medioppia cf. subpectinata</i> (OUDEMANS, 1901)	-/+	0/0	0/0	0/0	0/0	0/0	0/0	1/5
<i>Medioppia</i> sp.	+/-	0/0	0/0	0/0	0/0	0/0	0/0	1/0
<i>Micropoppia minus</i> (PAOLI, 1908)	-/+	0/0	0/0	0/0	0/0	0/0	0/1	0/1

Table 1 (continued)

Family, species	99/05	AS1	AS2	AS3	VB	ES5	ES6	ES7
<i>Oppia concolor</i> (C. L. KOCH, 1844)	-/+	0/0	0/0	0/0	0/3	0/0	0/0	0/1
<i>Oppia cf. manifera</i> HAMMER, 1952	-/+	0/0	0/0	0/0	0/0	0/0	0/0	0/1
<i>Oppia</i> sp.1	-/+	0/0	0/0	0/0	0/0	0/0	0/1	0/0
<i>Oppia</i> sp.2	+/-	0/0	0/0	0/0	0/0	3/0	1/0	5/0
<i>Oppia</i> sp.3	+/-	0/0	0/0	2/0	1/0	2/0	0/0	0/0
<i>Oppiella nova</i> (OUDEMANS, 1902)	+/+	0/1	0/0	0/0	5/0	0/0	0/1	1/0
<i>Oxyoppioides decipiens</i> (PAOLI, 1908)	-/+	0/0	0/1	0/0	0/0	0/0	0/0	0/0
<i>Ramusella mihelcici</i> PEREZ-INIGO, 1965	+/+	2/0	0/0	0/0	0/19	0/7	11/15	7/0
<i>Subiasella cf. maculata</i> (HAMMER, 1952)	-/+	0/0	0/0	0/1	0/0	0/0	0/0	0/0
QUADROPPIIDAE								
<i>Quadroppia quadricarinata</i> (MICHAEL, 1885)	+/+	0/0	0/0	0/0	0/0	2/4	7/2	1/0
SUCTOBELBIDAE								
<i>Allosuctobelba grandis</i> (PAOLI, 1908)	+/-	0/0	1/0	0/0	0/0	0/0	0/0	0/0
<i>Suctobelba trigona</i> (MICHAEL, 1888)	+/+	0/0	0/0	0/0	0/0	2/2	2/0	0/0
<i>Suctobelba cf. arcana</i> MORITS, 1970	+/-	0/0	0/0	0/0	1/0	0/0	0/0	0/0
<i>Suctobelba singularis</i> (STRENZKE, 1950)	+/-	0/0	0/0	0/0	1/0	0/0	0/0	0/0
<i>Suctobelba</i> sp.	+/-	0/0	0/0	0/0	1/0	0/0	0/0	0/0
<i>Suctobelba tuberculata</i> (STRENZKE, 1950)	+/+	0/0	0/0	0/0	1/1	0/0	1/0	0/0
LICNEREMAEIDAE								
<i>Licneremaeus cf. licnophorus</i> (MICHAEL, 1882)	+/+	0/0	0/0	0/0	0/1	0/8	1/15	2/1
PASSALAZETIDAE								
<i>Passalozetes africanus</i> GRANDJEAN, 1932	+/+	0/1	2/3	8/4	0/18	0/0	0/0	0/0
SCUTOVERTICIDAE								
<i>Scutovertex sculptus</i> MICHAEL, 1879	+/-	0/0	0/0	0/0	0/0	0/0	4/0	0/0
HAPLOZETIDAE								
<i>Haplozetes</i> sp.	-/+	0/0	0/1	2/0	1/0	0/0	0/0	2/0
ORIBATULIDAE								
<i>Simkinia montana</i> KRIVOLUTSKY & GRISHINA, 1970	-/+	0/0	0/0	0/0	0/0	0/3	0/15	0/5
<i>Zygoribatula exarata</i> (OUDEMANS, 1900)	+/-	0/0	0/0	0/0	3/0	0/0	0/0	1/0
<i>Zygoribatula frisiae</i> (OUDEMANS, 1900)	+/+	0/0	4/0	0/0	2/1	1/0	25/0	10/0
PROTORIBATIDAE								
<i>Liebstadia similes</i> (MICHAEL, 1888)	+/+	8/1	0/0	0/0	0/1	17/0	0/0	4/0
<i>Protoribates monodactylus</i> (HALLER, 1884)	+/-	0/0	0/0	0/0	0/0	1/0	0/0	0/0
<i>Protoribates</i> sp.	+/-	11/0	0/0	1/0	0/0	0/0	0/0	0/0
XYLOBATIDAE								
<i>Xylobates capucinus</i> (BERLESE, 1908)	-/+	0/0	0/0	0/0	0/0	0/0	0/1	0/0

Table 1 (continued)

Family, species	99/05	AS1	AS2	AS3	VB	ES5	ES6	ES7
<i>Xylobates (Hemileius) cf. elongatus</i> MIHELICIC, 1955	-/+	0/7	0/8	0/3	0/1	0/0	0/0	0/0
<i>Xylobates novus</i> WILLMANN, 1953	+/-	0/0	0/0	1/0	0/0	0/0	0/0	1/0
SCHELOBATIDAE								
<i>Hemileius cf. elongatus</i> PEREZ-INIGO, 1978	+/-	5/0	1/0	1/0	0/0	0/0	6/0	1/0
<i>Schelorbates laevigatus</i> (KOCH, 1835)	+/+	2/1	1/0	1/0	0/1	0/1	0/1	12/0
<i>Schelorbates latipes</i> (KOCH, 1841)	+/+	0/0	0/0	0/0	1/1	0/9	11/16	4/21
<i>Schelorbates longus</i> KULIJEW, 1963	+/-	0/0	0/0	0/0	0/0	0/0	0/0	11/0
<i>Schelorbates</i> sp.	+/-	0/0	0/0	0/0	0/0	0/0	1/0	0/0
ZETOMOTRICHIDAE								
<i>Ghilarovus humeridens</i> KRIVOLUTSKY, 1966	+/-	0/0	5/0	0/0	0/0	0/0	0/0	0/0
CERATOZETIDAE								
<i>Ceratozetes gracilis</i> (MICHAEL, 1884)	+/-	0/0	0/0	0/0	0/0	1/0	0/0	0/0
<i>Fuscozetes setosus</i> (KOCH, 1839)	+/-	0/0	0/0	0/0	0/0	0/0	1/0	0/0
<i>Globozetes longipilus</i> SELLNICK, 1928	+/-	0/0	0/0	0/0	0/0	1/0	0/0	0/0
<i>Globozetes</i> sp.	-/+	0/0	0/0	0/1	0/0	0/0	0/0	0/0
CHAMOBATIDAE								
<i>Chamobates borealis</i> (TRAGARDH, 1902)	+/-	0/0	0/0	0/0	0/0	0/0	0/0	1/0
<i>Chamobates caucasicus</i> SHALDYBINA, 1969	+/+	0/0	0/0	0/0	0/2	1/2	0/6	0/9
<i>Chamobates cuspidateformes</i> (TRAGARDH, 1904)	-/+	0/0	0/0	0/0	0/0	0/0	0/0	0/2
<i>Chamobates dentotutorii</i> SHALDYBINA, 1969	+/-	0/0	0/0	0/0	0/0	0/0	0/0	1/0
<i>Chamobates cf. depauperatus</i> (BERLESE)	+/-	0/0	0/0	0/0	1/0	0/0	0/0	0/0
<i>Chamobates subglobulus</i> (OUDEMANS, 1900)	+/+	0/0	0/0	0/0	0/0	1/5	0/12	1/0
MYCOBATIDAE								
<i>Minunthozetes pseudofusiger</i> (SCHWEIZER, 1922)	-/+	0/0	0/0	0/0	0/0	0/0	0/0	0/1
<i>Punctoribates mundus</i> SHALDYBINA, 1973	+/-	0/0	0/0	0/0	0/0	1/0	0/0	1/0
<i>Punctoribates punctum</i> (KOCH, 1839)	+/+	0/0	0/0	0/0	0/0	7/1	2/5	20/0
PHENOPELOPIDAE								
<i>Eupelops nepotulus</i> (BERLESE, 1916)	+/-	1/0	0/0	0/0	0/0	2/0	6/0	2/0
<i>Eupelops</i> sp.	-/+	0/2	0/0	0/1	0/0	0/0	0/0	0/0
<i>Eupelops cf. subuliger</i> (BERLESE, 1917)	+/+	0/1	0/0	1/0	0/1	1/1	0/3	1/1
<i>Eupelops torulosus</i> (C. L. KOCH, 1836)	-/+	0/0	0/0	0/1	0/1	0/1	0/0	0/0
<i>Peloptulus phaenotus</i> (KOCH, 1844)	+/-	1/0	0/0	0/0	0/0	0/0	0/0	0/0
ORIBATELLIDAE								
<i>Latilamellobates clavatus</i> (MIHELICIC, 1956)	-/+	0/0	0/1	0/0	0/0	0/0	0/0	0/0
<i>Oribatella</i> sp.	+/-	0/0	0/0	0/0	0/0	0/0	0/0	6/0

Table 1 (continued)

Family, species	99/05	AS1	AS2	AS3	VB	ES5	ES6	ES7
<i>ACHIPTERIIDAE</i>								
<i>Achipteria nitens</i> (NICOLET, 1855)	-/+	0/1	0/0	0/0	0/0	0/0	0/0	0/0
<i>Parachipteria petiti</i> TRAVÉ, 1960	+/-	0/0	0/0	0/0	0/0	0/0	1/0	0/0
<i>Parachipteria cf. willmanni</i> TRAVÉ, 1960	+/+	1/0	0/0	0/0	0/1	12/1	6/0	2/1
<i>Tectoribates</i> sp.	-/+	0/0	0/0	0/0	0/0	0/11	0/10	0/0
<i>GALUMNIDAE</i>								
<i>Allogalumna italica</i> (JACOT, 1935)	-/+	0/0	0/0	0/0	0/0	0/0	0/3	0/1
<i>Galumna dimorpha</i> KRIVOLUTSKAJA, 1952	+/+	0/0	0/0	1/0	0/7	0/0	1/0	0/0
<i>Galumna obvia</i> (BERLESE, 1914)	+/-	0/0	0/0	1/0	0/0	0/0	0/0	0/0
<i>Galumna</i> sp.	+/+	1/0	0/0	1/0	1/0	1/2	8/0	0/0
<i>Galumna cf. tarsipennata</i> OUDEMANS, 1914	-/+	0/0	0/0	0/0	0/7	0/9	0/0	0/0
<i>Pergalumna altera</i> (OUDEMANS, 1915)	-/+	0/0	0/0	0/0	0/0	0/1	0/0	0/0
Total species		24/14	16/17	19/10	20/27	35/45	36/42	49/42
Abundance	93/ 87	63/ 24	55/ 31	32/ 20	28/ 96	134/ 327	164/ 461	183/ 280

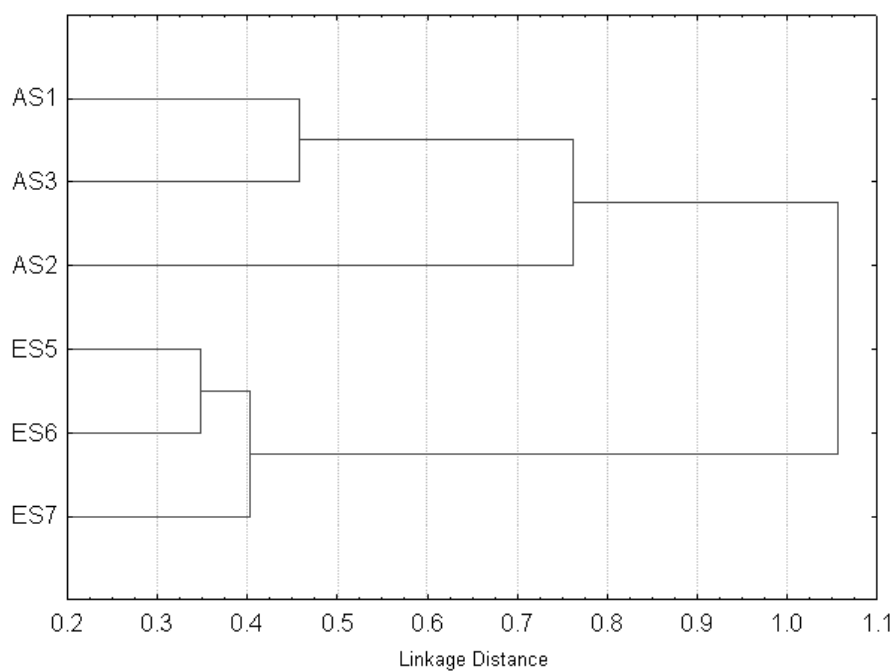
**Fig. 1.** Linkage distance between stations at "EC" based on the Sørensen similarity index. Amalgamation rule: Ward's method

Table 2. Ranking of station at “EC” according to increasing species richness in different phylogenetic groups. Ranking of Basidiomycetes and Bryophyta was identical. Factor 1 and Factor 2 explain the estimated variability in the Spearman correlation matrix by means of factor analysis.

Group	AS1	AS2	AS3	ES5	ES6	ES7	Factor 1	Factor 2
Mites [*]	3	2	1	5	4	6	0.871	0.397
Reptiles ^{1*}	6	5	4	1	2	3	-0.845	0.476
Soil fungi ^{2-7*}	2	3	1	5	6	4	0.949	-0.074
Rhopalocera ^{3*}	4.5	6	4.5	1.5	1.5	3	-0.874	0.145
Orthoptera ⁴	2.5	5	6	2.5	2.5	2.5	-0.750	-0.571
Dermestidae ⁵	4	4	6	4	1	2	-0.757	-0.364
Chrysomelidae ^{5*}	4	5	6	2	3	1	-0.871	-0.397
Collembola ^{6*}	2	3	1	6	4.5	4.5	0.958	-0.043
Basidiomycetes ^{7*} + Bryophyta ^{7*}	1.5	3	1.5	6	5	4	0.948	-0.254
Tenebrionidae ^{5*}	5	4	6	2	2	2	-0.976	-0.076
Trees+shrubs ^{8*}	1	2.5	2.5	5	6	4	0.880	-0.395
Eigenvalue							9.478	1.320
Proportion of the total							0.790	0.110

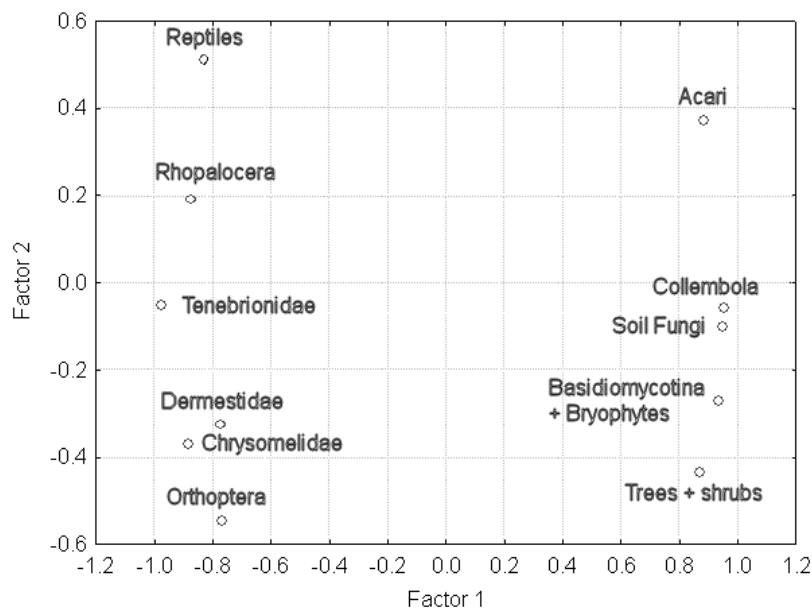


Fig. 2. Plot showing distribution of different phylogenetic groups according to two identified differentiating factors at “EC”. Factor 1 was identified with the interslope distribution and, factor 2, with the distribution of species richness along the slopes

Table 3. Distribution of identified zoogeographic species groups at “EC”

Category	AS (N = 45)	ES (N = 86)	P*
Cosmopolitan	8 (0.18)	14 (0.16)	0.91
Holarctic	9 (0.20)	19 (0.22)	0.90
Palaearctic (+ S Palaearctic)	14 (0.31)	32 (0.37)	0.70
Euro – East Mediterranean	10 (0.22)	16 (0.19)	0.85
Mediterranean	1 (0.02)	2 (0.02)	?
Asiatic	3 (0.07)	3 (0.03)	0.83

*probability of the interslope differences was computed from the differences in two proportions by means of Statistica for Windows.

per parts of slopes, *e.g.*, Rhopalocera and reptiles (Table 2 and Fig. 2). In total, only two factors were needed to describe the variance (90% in total) in the Spearman correlation matrix based on group ranking presented in Table 2. Inter-station mite distribution was positively and significantly correlated with distribution of Collembola ($R = 0.84$, $p = 0.04$) but not with other groups, water availability, temperature, and general plant cover.

Zoogeographic affinities of mites collected at “EC”

The majority of mites collected at “EC” were widely distributed, *i.e.*, cosmopolitan, Holarctic, Palaearctic, and Euro-East Mediterranean (Table 3). No interslope differences in the proportion of species of different zoogeographic affinities were detected (Table 3). However, this result might be influenced by small sample sizes, poor detailed knowledge of the mite distributions, and that many species were identified at the genera level only (Table 1).

DISCUSSION

Species richness

The high number of free living oribatid mites identified at “EC” indicates a high level of inter-sample heterogeneity, but the number of identified species per slope is similar to the estimated 40–70 species present at any site in the temperate forest ecosystem (*e.g.*, LUXTON 1975, NORTON 1985). The number of species collected in 1999/2005 was similar, 93 and 87 species, but many species were missing either in the 1999 list or in the 2005 list. This could be attributed to the collection error and/or to the species turnover (DIAMOND & MAY 1977), but only a long-term

regular sampling could illuminate the underlying factors underlying presence-absence alternation of number of species. Significantly higher species richness of oribatid mites was found on the ES compared to the AS in the previously identified “water-dependent” groups (Collembola, bushes and trees, Basidiomycotina, Bryophytes, and soil fungi). In regard to trees and bushes, available data strongly implicate water availability as a key constraint on abundance at “EC” (NEVO *et al.* 1999) and globally in warm areas where energy is abundant (HAWKINS *et al.* 2003). In Basidiomycotina, their overall diversity is apparently the highest in areas of abundant rainfall and in some groups in areas of intermediate to abundant rainfall (LODGE *et al.* 1995). However, two factors – water availability and ectomycorrhizis – might contribute to the interslope differences in species richness since many species of Basidiomycotina are ectomycorrhizal species related to the distribution and diversity of their host plants (*e.g.*, *Quercus caliprinos*) more abundant on the ES than AS. Soil fungi behave in a similar way to Basidiomycotina showing higher species richness on the ES compared to the AS possibly because the spore germination depends on the availability of free water. Mosses represent a typical water-dependent group that reproduces only in a mesic environment (PHARO *et al.* 1999), have very limited control of the uptake and water loss (SCOTT 1994), and even lack roots and draw most of their water and nutrients from the atmosphere. Springtails (Collembola) are known to aggregate in highly moist environments where there are decaying plant materials (BONNET *et al.* 1975). The interslope differences and similarities between distribution of oribatid mites and “water-dependent” groups indicate that water availability plays a major role in the mite distributions. Similarly, NOTI *et al.* (2003) concluded that the soil relative humidity might be one of the factors responsible for differences in species richness between a tropical forest and savannah. It is worth noting that soil habitat associations with different dominant plants seem to have little effect on mite species composition (CURRY & GANLEY 1977, MACFADYEN 1952, OSLER & BEATTIE 2001).

However, in contrast to other “water-dependent groups” the mite species richness and abundance increased upslope in contrast to water availability. This fact indicates the presence of an additional environmental factor playing a role in the mites’ interslope distribution. Unfortunately, many factors contributing to soil complexity and possibly influencing the biodiversity of soil invertebrates, such as structure, texture, porosity, water holding capacity etc., were not studied at the microsite. It is worthy to note that in other groups the increase in species richness upslope (*e.g.*, reptiles, Rhopalocera) might be connected with the availability of ambient energy since both groups are known for their physiological and behavioral (sun-basking) adjustment for heat gain (COWLES & BOGERT 1944, CLENCH 1966) and their global or regional distributions are mostly constrained by ambient energy

input (HAWKINS *et al.* 2003, TURNER *et al.* 1987). In conclusion, water, energy, or water-energy balance might be the most important factors of the mites distribution as clearly indicated in the global distribution of many phylogenetic groups (HAWKINS *et al.* 2003).

CONCLUSIONS

Oribatid mites showed significant interslope differentiation patterns at “EC”, indicating that the evolutionary forces responsible for species richness at the microsite can be the same as on a global level. The study shows that local ecological gradients and contrasts are important to keep high local diversity that certainly contributes to the high species richness characterizing the Mediterranean ecosystems.

*

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