

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/324711910>

# Comparison of terrestrial isopod (Crustacea: Oniscidea) assemblages from two preserved areas (Bouhedma and Chambi) in arid regions

Article in *The European Zoological Journal* · January 2018

DOI: 10.1080/24750263.2018.1455902

CITATIONS

2

READS

222

4 authors, including:



**Wahiba Zaabar**

University of Tunis El Manar

15 PUBLICATIONS 57 CITATIONS

[SEE PROFILE](#)



**M.F. Bouslama**

21 PUBLICATIONS 426 CITATIONS

[SEE PROFILE](#)



**Achouri Mohamed Sghaier**

University of Tunis El Manar

41 PUBLICATIONS 302 CITATIONS

[SEE PROFILE](#)

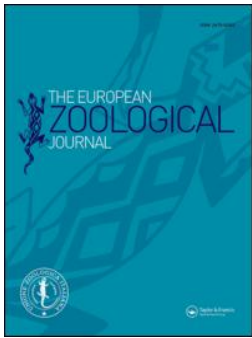
Some of the authors of this publication are also working on these related projects:



Applied ecology and biodiversity [View project](#)



Systematic and diversity of Terrestrial isopods (Crustacea, Isopoda) [View project](#)



## Comparison of terrestrial isopod (Crustacea: Oniscidea) assemblages from two preserved areas (Bouhedma and Chambi) in arid regions

M. Khila, W. Zaabar, M. F. Bouslama & M. S. Achouri

To cite this article: M. Khila, W. Zaabar, M. F. Bouslama & M. S. Achouri (2018) Comparison of terrestrial isopod (Crustacea: Oniscidea) assemblages from two preserved areas (Bouhedma and Chambi) in arid regions, *The European Zoological Journal*, 85:1, 159-169, DOI: [10.1080/24750263.2018.1455902](https://doi.org/10.1080/24750263.2018.1455902)

To link to this article: <https://doi.org/10.1080/24750263.2018.1455902>



© 2018 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.



Published online: 23 Apr 2018.



Submit your article to this journal [↗](#)



Article views: 153



View Crossmark data [↗](#)



## Comparison of terrestrial isopod (Crustacea: Oniscidea) assemblages from two preserved areas (Bouhedma and Chambi) in arid regions

M. KHILA, W. ZAABAR, M. F. BOUSLAMA, & M. S. ACHOURI

Faculty of Sciences of Tunis, Bio-Ecology and Evolutionary Systematic, University of Tunis El Manar, Manar, II, Tunisia

(Received 23 October 2017; accepted 15 March 2018)

### Abstract

A total of 1290 specimens belonging to 11 species and four families were captured in two national parks, Bouhedma and Chambi. Among these species, seven belonged to Porcellionidae, and the remaining species represented Agnaridae, Armadillidae and Armadillidiidae families. Five species were common and recorded in both parks. However, *Armadillidium tunisiense*, *Hemilepistus reaumurii* and *Porcellio djahizi* were recorded only in Chambi while *Agabiformius lentus*, *Armadillo officinalis* and *Porcellio albinus* were collected only in Bouhedma. The distribution structure of the collected species was analyzed according to altitude and plant assemblages. Seasonal sampling showed that the highest abundance and species richness were recorded in spring. In both parks, the species richness decreased as the altitude increased. Arid regions sheltered specific species such as *H. reaumurii* and *P. albinus*, which were often the dominant component of the arthropod macrodecomposer guild in some habitats. The similarity analysis showed a quantitative and qualitative difference between the two parks. The two parks Bouhedma and Chambi shared five species (*Leptotrichus panzerii*, *Porcellio laevis*, *P. variabilis*, *Porcellionides pruinosus*, *Armadillidium sulcatum*) with areas studied in the north of Tunisia, Kroumirie, supralittoral zones and around the wetlands.

**Keywords:** Oniscidean diversity, altitudinal gradient, arid region and mountain, seasonal pattern, species richness

### Introduction

The diversity of terrestrial isopod species is directly connected with the number of microhabitats, which allow the coexistence of several species (Lopes et al. 2005). Terrestrial isopods, as members of the soil fauna, are expected to respond to environmental changes given their limited dispersal abilities. They are probably very sensitive to changes in soil chemical and physical properties (Paoletti & Hassall 1999), thus responding rapidly to environmental changes (Nakamura et al. 2003). Many studies have shown the influence of the general characteristics of the area on the terrestrial isopods (Hotea et al. 2003; Mureşan et al. 2003; Tomescu et al. 2008, 2011). Hence, knowledge of the isopod faunal richness of a region is one of the factors responsible for success in monitoring and conserving biodiversity (Lopes et al. 2005).

In North Africa, while the diversity of terrestrial isopods in humid regions was studied in the past by

Dollfus (1896), Gadeau De Kerville (1909), Arcangeli (1932), Zavattari (1934), Vandel (1956a,b, 1958a,b,c), Caruso and Di Maio (1990) and more recently the isopod fauna was studied through the MEDCORE project by Achouri et al. (2008a), Colombini et al. (2008), Charfi-Cheikhrouha and El Gtari (2008), Achouri and Charfi-Cheikhrouha (2009) and Taiti and Rossano (2015), the diversity of terrestrial isopod communities in arid regions has not received much attention in the isopodological literature.

In Tunisia, some studies were performed on reproductive behavior, systematics and geographical distribution of species of the genera *Hemilepistus*, *Porcellio*, *Porcellionides* and *Armadillidium* (Rezig & Nasri 1992; Medini & Charfi-Cheikhrouha 1998; Achouri & Charfi-Cheikhrouha 2002; Achouri et al. 2002; Medini-Bouaziz et al. 2006, 2015, 2016). In the last few decades, other investigations have been performed as part of a broader study aiming to assess the biodiversity of terrestrial isopods in humid zones

in Tunisia (Fraj et al. 2010; Hamaïed-Melki et al. 2011; Hamaïed et al. 2013).

Protected areas have restrictions on human activities aiming at preserving biotic and abiotic components of the landscape. The present study contributes to our knowledge of the diversity of terrestrial isopod communities in two national parks, Bouhedma and Chambi, in arid regions in Tunisia. Both Kremen et al. (1993) and Massa and Ingegnoli (1999) reported that “the diversity and abundance of terrestrial arthropods can provide a rich base of information to aid efforts in the conservation of biodiversity and the planning and management of nature reserves”. In addition, the isopods in the remaining forests and steppes facing desertification, if well preserved, may play an important role in the local food webs.

Thus, we intend to present data on the community of terrestrial isopods in arid regions, which are currently insufficiently studied, and threatened by drought and desertification due to global climate change. Specific objectives were (1) to make a list of terrestrial isopod species recorded in both Bouhedma and Chambi parks; (2) to analyze their distribution according to season, altitudinal gradient and plant associations; and (3) to determine which species are present in these areas, and also to describe any clear eco-morphological characteristics (Schmalfuss 1984) associated with different habitat types.

## Material and methods

### Sampling areas

The first site, the Bouhedma National Park (Figure 1), is located in southern Tunisia (34°39'N,

9°48'E). It stretches 85 km east of Gafsa, 100 km south of Sidi Bouzid, 105 km west of Sfax, 100 km northwest of Gabes. It covers an area of 16,488 ha of which 8804 ha are fully protected. It is considered among the last savanna gum in North Africa covered by *Acacia tortilis* subsp. *raddiana* with *Retama raetam*, *Cenchrus ciliaris* and *Digitaria commutata* (Zaafouri et al. 1994). In 2010 it became a part of the “World Network of Biosphere Reserves” (WNBR) after having already been a part of “Man and the Biosphere Programme” (MAB) since 1971. Bouhedma Park is located in an arid bioclimatic zone (Chaieb & Boukhris 1998) where the mean annual rainfall varies between 100 and 200 mm (Abdallah et al. 2008). In this area, three habitats were selected according to an elevation gradient ranging from 120 to 210 m and also according to vegetal associations (Table I).

The second study area, the National Park of Chambi (Figure 1), which has been a part of the WNBR since 1977 and a part of the MAB since 1971, belongs to the governorate of Kasserine. Its total area is 6723 ha. This park has the distinction of being representative of all the conditions of the Tunisian Atlas. It belongs to the area of the central highlands and has the highest peak in Tunisia, namely “Jebel Chambi”, with an altitude of 1544 m.

The vegetation of Chambi consists of a remarkable assemblage of plant groups ranging from the green oak (*Quercus ilex*) in the summit rocks to the steppe alfa (*Stipa*) in the piedmont. The undergrowth of the pine forests of Aleppo consists of *Juniperus phoenicea*, *J. oxycedrus*, *Cistus*, *Globularia* and *Rosmarinus*. The National Park of Chambi is divided into seven zones according to altitudinal gradient and plant associations (Table I). In this park, seven habitats were investigated, one in each zone.

Table I. Characteristics of the sampling habitats in Bouhedma (Bouh 1–Bouh 3) and Chambi (Cham 1–Cham 7).

Sampling habitat	Altitude (m)	Vegetal characteristics	Soil characteristics
Bouh 1, exposed to anthropogenic impact	120	Reforestation of <i>Eucalyptus camaldulensis</i> , <i>Acacia</i> sp., palms	Sandy soil, medium and coarse
Bouh 2, open acacia savannah	190	Tree stratum formed by <i>Acacia tortilis</i>	Loamy soil
Bouh 3, sparse vegetation	210	Shrub layer with two <i>Gramineae</i> <i>Cenchrus ciliaris</i> , and <i>Digitaria commutata</i>	Sandy soil
Cham 1, sparse vegetation of halophytes	750	<i>Atriplex</i> and other halophytes	Sandy loam soil
Cham 2, open steppe of <i>Stipa</i> and <i>Artemisia</i> exposed to anthropogenic impact	900	<i>Stipa tenacissima</i> , <i>Globularia alypum</i> and <i>Rosmarinus officinalis</i>	Limestone soil
Cham 3, dense forest	1100	Aleppo pine forest, <i>Stipa tenacissima</i> and <i>Rosmarinus officinalis</i>	Rendzine ground
Cham 4, dense forest	1200	Aleppo pine forest and <i>Juniperus phoenicea</i>	Rendzine ground
Cham 5, dense forest	1300	Aleppo pine forest and <i>Juniperus oxycedrus</i>	Marl soil
Cham 6, open forest	1400	Aleppo pine forest	Marl soil
Cham 7, open maquis	1500	Maquis with green scrub, <i>Quercus ilex</i> and Aleppo pine	Marl soil

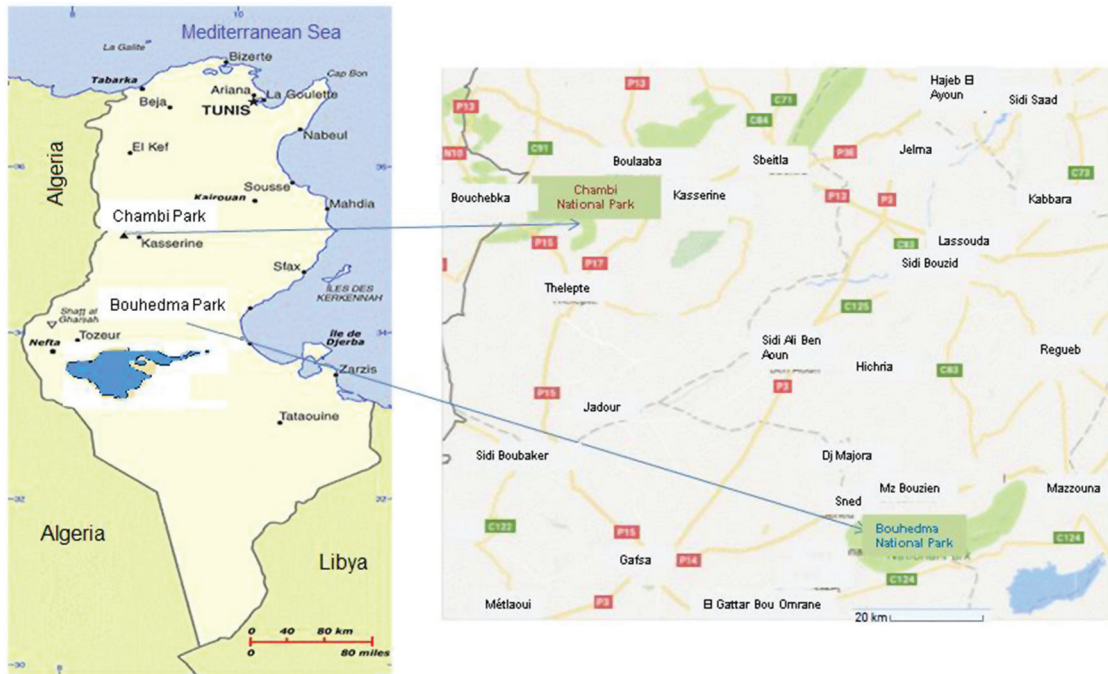


Figure 1. Tunisian map showing the location of the two national parks, Chambi and Bouhedma.

From January 2010 to October 2012, seasonal samplings were carried out (Table II). In each habitat, specimens were collected only once per

season (Table II), using 30 (0.5 × 0.5 m) quadrates randomly distributed. The rocks, soil and dead leaves were lifted using a small pallet, while

Table II. Temporal distribution of terrestrial isopod species in different sampling seasons in Bouhedma and Chambi parks.

	30 January 2010	26 April 2010	24 July 2010	27 October 2010	30 January 2011	26 April 2011	24 July 2011	27 October 2011	30 January 2012	28 April 2012	29 July 2012	30 October 2012
<i>Agabiformius lentus</i>	2	3	1	1	2	4	1	2	5	6	0	4
<i>Leptotrichus panzerii</i>	4	13	1	7	4	8	0	7	5	17	1	12
<i>Porcellio laevis</i>	0	2	1	1	0	3	0	0	3	4	1	4
<i>Porcellio variabilis</i>	5	9	2	7	2	9	1	3	5	18	2	11
<i>Porcellionides pruinus</i>	1	4	1	1	0	6	0	2	4	7	1	5
<i>Armadillidium sulcatum</i>	2	5	0	1	1	3	0	1	4	7	0	3
<i>Armadillo officinalis</i>	0	3	0	0	2	1	0	1	3	4	0	2
<i>Armadillidium tunisiense</i>	7	15	2	19	9	17	4	11	15	35	1	17
<i>Hemilepistus reaumuri</i>	0	84	33	27	0	58	58	33	0	89	103	48
<i>Porcellio albinus</i>	11	28	1	24	13	17	0	15	17	46	2	28
<i>Porcellio djahizi</i>	14	15	2	17	6	10	1	10	15	27	2	19

(\*) January = winter; April = spring; October = autumn; July = summer.

the tree barks and palm trees were removed manually. In order to compare the results of this study to those obtained previously (Achouri et al. 2008a; Hamaïed-Melki et al. 2011; Hamaïed et al. 2013), and to get the same probability of capture, individuals were collected by three authors during a period of 1 hour. This time-effort procedure offered semi-quantitative information (Souty-Grosset et al. 2008). To complete the list of terrestrial isopods in the two parks, specimens were also collected by hand, but these were not included in the quantitative data.

Laboratory analysis

Collected specimens, preserved in 70% ethanol, were identified and sexed in the laboratory according to Vandel (1962) using a Leica M5 stereomicroscope (Leica Microsystems, Bensheim, Germany).

Data analysis

Different ecological indices estimating the diversity in the studied habitats were used, such as the Berger–Parker dominance index (May 1975), with  $d = N_{max}/N$ , ( $N_{max}$ , number of individuals of the most abundant species; and  $N$ , the total number of individuals). Total abundance of terrestrial isopods ( $N$ ), number of species ( $S$ ), Shannon–Wiener diversity index ( $H'$ ) (Shannon & Weaver 1963), and Pielou’s evenness index ( $J'$ ) (Pielou 1966) were calculated for each sample. The

difference between diversity indices ( $H'$  and  $J'$ ), across season and different altitude, was tested using one-way analysis of variance (ANOVA).

Non-metric multidimensional scaling (MDS; Kruskal & Wish 1978) was performed based on mean abundance of species at each sample. Thus, MDS could be considered an alternative to factor analysis. In general, the goal of the analysis was to detect meaningful underlying dimensions that allowed us to explain observed similarities or dissimilarities between the investigated variables. In factor analysis, the similarities between variables were expressed in the correlation matrix. With MDS, we could analyze any kind of similarity or dissimilarity matrix in addition to correlation matrices. Furthermore, Similarity Percentages (SIMPER) broke down the contribution of each species (or other variable) to the observed similarity (or dissimilarity) between samples. It allowed us to identify the species that were most important in creating the observed pattern of similarity. The PRIMER 5.0 (Plymouth Routines in Multivariate Ecological Research) software package (Clarke & Warwick 1994) was used to construct a complete linkage cluster analysis. Canonical correspondence analysis (CCA) was developed to allow ecologists to correlate the abundance of species to environmental variables (Ter Braak Cajo 1986). In our study, CCA was applied to correlate the species abundance to the altitudinal gradient and vegetal associations. This analysis was performed using the package Excel XLSTAT v. 7.5.2.

Table III. Spatial distribution of isopods in the two parks (Bouhedma and Chambi), relative abundance, and values of Shannon–Wiener ( $H'$ ) and evenness indexes ( $J'$ ).

Families	Species	Bouh 1 (120)	Bouh 2 (190)	Bouh 3 (210)	Cham 1 (750)	Cham 2 (900)	Cham 3 (1050)	Cham 4 (1200)	Cham 5 (1300)	Cham 6 (1400)	Cham 7 (1540)	Total habitats	N1	Relative abundance (%)
Porcellionidae	<i>A. lentus</i>	27	3	1	0	0	0	0	0	0	0	3	31	2.52
	<i>L. panzerii</i>	13	5	2	0	19	25	14	0	0	0	6	78	6.37
	<i>P. laevis</i>	8	0	0	1	8	0	0	0	0	0	2	17	1.39
	<i>P. variabilis</i>	13	7	11	0	28	15	0	0	0	0	5	74	6.01
	<i>P. pruinosus</i>	19	0	0	1	12	0	0	0	0	0	2	32	2.60
	<i>P. albinus</i>	11	112	79	0	0	0	0	0	0	0	3	202	16.43
	<i>P. djahizi</i>	0	0	0	0	25	46	33	19	15	0	5	138	11.23
Armadillidae	<i>A. officinalis</i>	0	7	9	0	0	0	0	0	0	0	2	16	1.30
Agnaridae	<i>H. veaumurii</i>	0	0	0	523	0	0	0	0	0	0	1	523	37.59
Armadillidiidae	<i>A. sulcatum</i>	17	1	2	0	7	0	0	0	0	0	4	27	2.19
	<i>A. tunisiense</i>	0	0	0	0	13	11	39	47	26	16	6	152	12.36
	N2	108	135	104	525	112	97	86	66	41	16		1290	
	S	7	6	5	3	7	4	3	2	2	1			
	$H'$	2.68	1.06	1.28	0.04	2.64	1.78	1.47	0.86	0.94	0			
	$J'$	0.95	0.41	0.55	0.03	0.94	0.99	0.92	0.86	0.94				

Notes: N1, total number of collected individuals of the same species; N2, total number of collected individuals in the same habitat. (\*) A, *Armadillidium*; Ag, *Agabiformius*; Ar, *Armadillo*, H, *Hemilepistus*, L., *Leptotrichus*; P., *Porcellio*, Pr., *Porcellionides*.



## Results

### Species composition

In the studied areas, 1290 individuals were collected: 347 from Bouhedma Park and 943 from Chambi Park. They belong to 11 species in the families Agnaridae, Porcellionidae, Armadillidiidae and Armadillidae (Table II). *Agabiformius lentus* (Budde-Lund, 1885), *Leptotrichus panzerii* (Audouin, 1826), *Armadillo officinalis* Duméril, 1816 and *Porcellio albinus* Budde-Lund, 1885 were only collected from Bouhedma Park. *Armadillidium tunisiense* Hamaïed & Charfi-Cheikhrouha, 2007, *Hemilepistus reaumurii* (Milne Edwards, 1840) and *Porcellio djahizi* Medini & Charfi-Cheikhrouha, 2001 were only captured in Chambi Park. In contrast, *Porcellio laevis* Latreille, 1804, *Porcellio variabilis* Lucas, 1849, *Porcellionides pruinosus* (Brandt, 1833) and *Armadillidium sulcatum* Milne Edwards, 1840 were common in both parks (Table III).

### Species richness, abundance and diversity

**Spatial variation.** The total numbers of each species recorded are summarized in Table III. Species richness ranged between 1 and 7. The habitats Bouh 1 and Cham 2 exhibited the highest species richness (7; Figure 2), while the habitat Cham 7 exhibited the lowest (1). Analyzing the spatial variation data by nested ANOVA, we found that there were no statistically significant differences between habitats in overall species richness of isopods recorded in the two parks ( $F = 1.627$ ,  $df = 16.28$ ,  $p = 0.22$ ). In fact, the species richness was negatively correlated with altitude ( $r^2 = 0.6452$ ), and no relationship was found

between the Shannon–Wiener index ( $H'$ ) and altitude ( $r^2 = 0.1543$ ). However, significant differences were found between species abundance related to altitude gradient (one-way ANOVA,  $F = 7.348$ ,  $df = 9.008$ ,  $p = 0.02395$ ).

**Temporal variation.** In terms of abundance, the ANOVA revealed significant differences between the parks throughout the years ( $F = 24.57$ ,  $df = 2$ ,  $p = 0.03$ ) and between seasons ( $F = 12.31$ ,  $df = 3$ ,  $p = 0.03$ ). In both studied parks, *H. reaumurii* was the most abundant species (37.59%), followed by *Porcellio albinus* (16.43%). *Armadillidium tunisiense* and *P. djahizi* were less abundant than the two previous species (12.36% and 11.53%, respectively). Despite its high abundance, *H. reaumurii* was only found in the first habitat in Chambi Park which was characterized by a sandy loam soil with *Atriplex* and other halophytes. *Armadillidium tunisiense* and *P. djahizi* occupied almost the same habitats, Cham 2 to Cham 7, which were characterized by high elevation (900 to 1500 m). However, *P. variabilis* and *L. panzerii* were the most frequent, and they were collected in five and six habitats, respectively, in the two parks (Table III). The Shannon–Wiener ( $H'$ ) and evenness ( $J'$ ) indexes showed seasonal fluctuations between habitats, with significant differences ( $F = 17.78$ ,  $df = 10.65$ ,  $p = 0.00$ ; and  $F = 24.55$ ,  $df = 9.23$ ,  $p = 0.00$ , respectively).

### Assemblages and species affinities

The MDS ordination analysis from quantitative data (Figure 3a) showed the existence of three groups (I, II and III, with a stress values of 0.04). Group I included samples collected in July 2010, July 2011

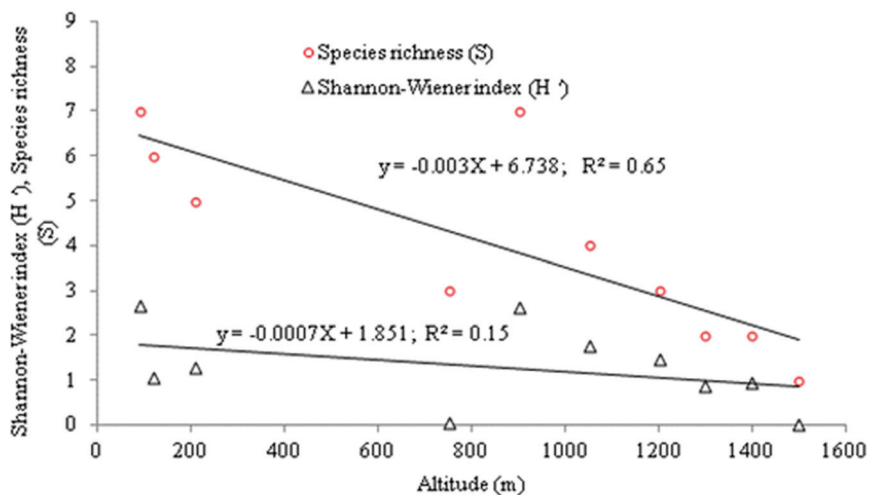


Figure 2. Relationship between altitude, species richness (S) and Shannon–Wiener index ( $H'$ ).

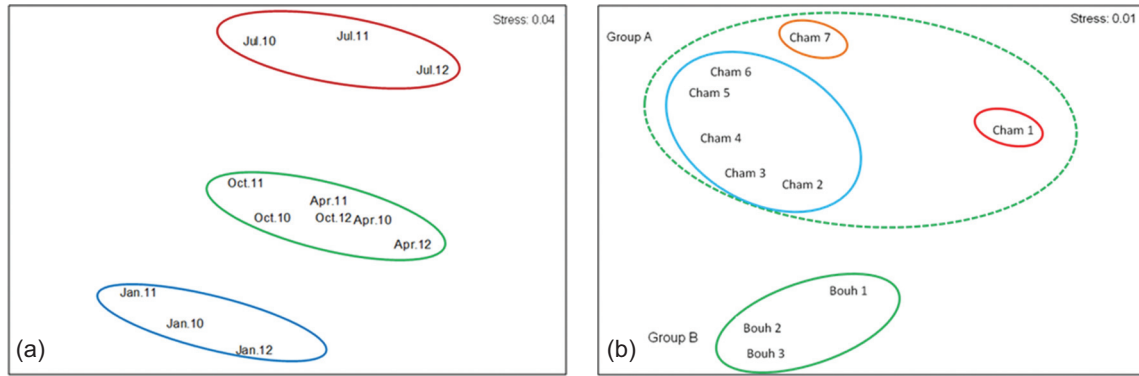


Figure 3. Multidimensional scaling plot based on species abundance. (a) season; (b) sampling habitats.

and July 2012, in which the number of recorded specimens was low except *H. reaumurii* in Chambi Park. Group II included samples collected in April and October in the overall period of study, in which a greater abundance of *P. djahizi* and *Ar. tunisiense* was recorded in Chambi, and *P. albinus* in Bouhedma. Group III included the samples of January 2010, 2011 and 2012, where *H. reaumurii* was totally absent.

Quantitatively, a significant difference was found between seasons in the global result (global  $R = 0.76$ ,  $p = 0.01$ ). The pairwise test results showed no significant differences between autumn–spring ( $R = 0.083$ ,  $p = 0.4$ ) and autumn–winter ( $R = 0.18$ ,  $p = 0.1$ ), but significant differences were found between winter–summer ( $R = 0.29$ ,  $p = 0.013$ ), winter–spring ( $R = 0.37$ ,  $p = 0.011$ ) and autumn–summer ( $R = 0.35$ ,  $p = 0.045$ ). The SIMPER analysis indicated that in autumn and summer, the species contributing most to the difference between seasons were *P. albinus*, *P. djahizi* and *Ar. tunisiense*, while in winter and spring, the most contributing species was *H. reaumurii*. The highest dissimilarities of SIMPER analysis were obtained between winter–summer (85.48%), winter–spring (57%) and autumn–summer (56.05%).

The MDS ordination analysis in Figure 3b, based on the abundance of collected species, suggested that the isopod assemblages could be grouped in two categories. The first, Group A, contains the seven habitats of Chambi Park, which revealed discrimination among three subgroups. The first subgroup (Cham 1) was characterized by the lowest altitude with halophyte vegetation and sheltered only *H. reaumurii*. The second was made of Cham 2, 3, 4, 5 and 6 where the diversity was inversely proportional to the altitude. The third one (Cham 7), with the highest altitude, showed a plant association of *Quercus ilex* and Aleppo pine, where only *A. tunisiense* was collected. The second,

Group B, is composed of the three habitats of Bouhedma Park. Bouh 1, a reforestation area of *Eucalyptus* and *Acacia*, exhibited the highest species richness (7), compared to Bouh 2 and 3, dominated by Gramineae, *C. ciliaris* and *D. commutata*. Nonetheless, the difference in abundance among these habitats was not significant.

#### *Distribution of isopods according to altitude, plant association and soil type*

The CCA was performed to correlate the distribution of isopod species to vegetation cover and altitude. Our analysis showed that 71.49% of the information (Figure 4) was obtained by adding the first two axes together, of which 53.38% was displayed by the first axis alone. Cham 1 was positively correlated to the first axis (F1) and habitats Cham 3 to Cham 7, characterized by high altitude and vegetal associations composed of Aleppo pine forest, *Juniperus phoenicea*, *J. oxycedrus* and *Quercus ilex*, were also positively correlated with F1. However, Bouh 1 was negatively correlated with F1. Bouh 2, a degraded meadow formed by *Acacia tortilis*, and Bouh 3, an open area dominated by two Gramineae, *Cenchrus ciliaris* and *Digitaria commutata*, were positively correlated with F2, whereas Cham 2, characterized by a steppe of *Stipa*, *Globularia* and *Rosmarinus* on limestone soil, was negatively correlated with the axis F2. Hence, *H. reaumurii* was clearly associated with Cham 1 characterized by a vegetal association of *Atriplex* and other halophytes on a sandy loam soil. *Armadillidium tunisiense* and *P. djahizi* were clearly related with Cham 3–7. *Armadillo officinalis* and *P. albinus* were related to Bouh 2 and Bouh 3, while *A. lentus*, *A. sulcatum*, *P. laevis*, *P. variabilis* and *P. pruinosus* were related to Bouh 1 and Cham 2.



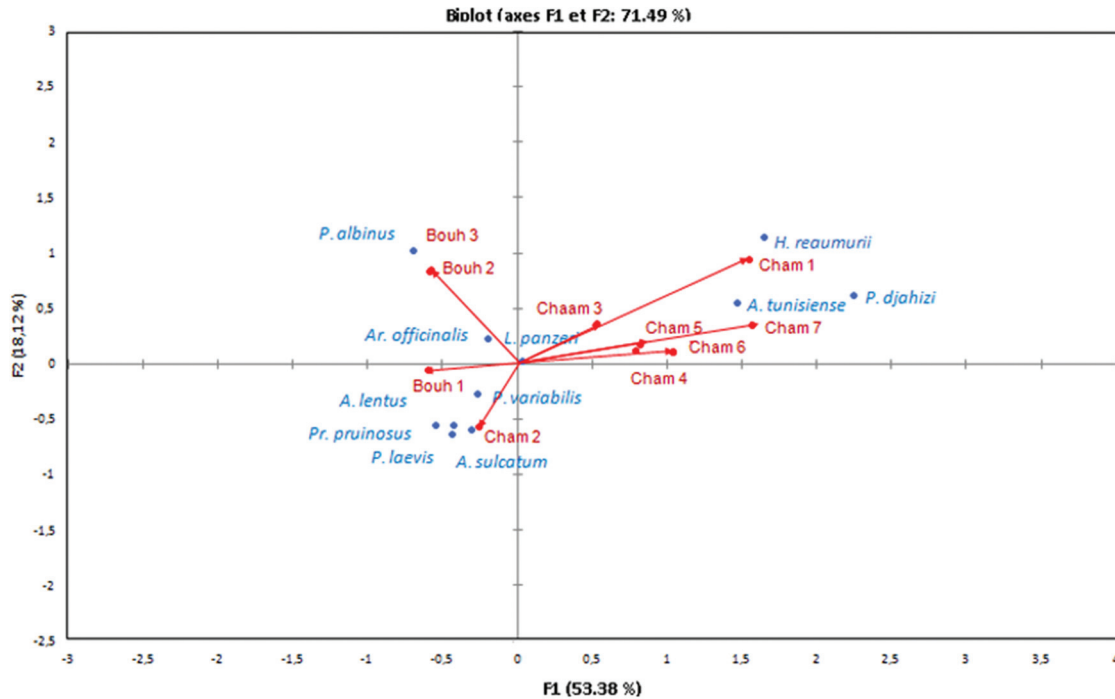


Figure 4. Canonical correspondence analysis (CCA) of isopod species, altitude and habitat type. Abbreviations: Bouh 1, 2, 3 and Cham 1, 2, 3, 4, 5, 6, 7 – habitats in Bouhedma Park and Chambi Park, respectively.

## Discussion

The composition of isopod assemblages differed in the two parks. Despite their relatively equal species richness (8), Bouhedma and Chambi showed a quantitative difference in collected specimens – 347 and 943, respectively. Within the studied parks Bouhedma and Chambi, the five common species were represented by a different number of specimens depending on habitat and sampling period. *Leptotrichus panzerii* and *P. variabilis* were the most common species, collected in five and six habitats from the two parks, respectively. The presence of *P. variabilis* in both parks suggests that this species is able to use a variety of habitats, as previously reported (Medini & Charfi-Cheikhrouha 1998; Medini-Bouaziz et al. 2015). *Armadillidium sulcatum*, collected in all habitats in Bouhedma and in the second habitat of Chambi, characterized by morphological and ecological variability in Tunisia (Hamaïed-Melki 2008), was capable of adapting to habitats with harsh conditions. As they were usually collected in places linked to human activities, the presence of *P. pruinus* and *P. laevis* in Bouh 1 and Cham 2, more exposed to anthropogenic impact, can be explained by the adjacent motels and other buildings which are favorable habitats for synanthropic species.

Besides the species common to both parks, there were characteristic species of each one. In Chambi Park, the exclusive existence and high abundance of *H. reaumurii* in the first habitat (Cham 1) suggests that this species is linked to soil type (sandy loam soil) and halophytes (Linsenmair 1984, 2007; Nasri & Morgan 2005). *Armadillidium tunisiense* and *P. djahizi* were the most common isopod species in this park; their presence in large number of specimens, from Cham 2 to Cham 7, suggests that these species are able to use a variety of habitats, as previously reported (Medini & Charfi-Cheikhrouha 2001; Hamaïed & Charfi-Cheikhrouha 2007). In Bouhedma Park, the small species *A. lentus* was collected mainly in the first habitat (Bouh 1) and sporadically in the two other habitats (Bouh 2 and 3). In fact, for smaller species, the preferences of microhabitats are satisfied by the existence of small places of shelter, regardless of the general characteristics of the habitat (Vilisics et al. 2007, 2011). Thus, the small number of captured individuals indicates the scarcity of favorable microhabitats in the Bouhedma Park. The presence of *A. officinalis*, reported as xerophilic (Vandel 1962; Messina et al. 2011), was expectable. In North Africa this species was very common in Benghazi, Lybia (Aljatlaoui & Nair 1994), in Egypt (Kheirallah 1980), and also in Morocco (Taiti &

Rossano 2015). *Porcellio albinus*'s high abundance in Bouhedma Park suggests its preference for arid and presaharian areas. Some authors have attributed that to its preference for desert regions (Medini-Bouaziz et al. 2016). It has been reported that *P. albinus* (Linsenmair 1984; Fraj et al. 2008) and *H. reaumurii* (Shachak & Yair 1984; Baker 2004, 2005) dig burrows. Moreover, for survival and reproduction, *H. reaumurii* in Chambi Park and *P. albinus* in Bouhedma Park shelter from the extreme heat and dryness in burrows. *Porcellio albinus* digs in loose soil and sandy dunes (Medini-Bouaziz et al. 2016, 2017) while *H. reaumurii* digs in only solid soil (Nasri et al. 1996; Linsenmair 2007).

Regarding the diversity of the isopod communities, relative abundance and species richness values decreased with altitude in both parks. Additionally, the highest diversity values were recorded in open habitats (Bouh 1, 2 and Cham 2). These are likely to be more favorable for isopods than forests with dense vegetation (Cham 3, 4, 5, 6) or dense maquis (Cham 7). However, it was expected that protected areas with dense vegetation should provide more favorable conditions for isopods as they offer abundant food resources. Sfenthourakis et al. (2005) and Hamaïed-Melki et al. (2011) reported that open habitats with a mixture of shrubby vegetation are more favorable for isopods than mono-dominant forests, or very dense vegetation. Moreover, *H. reaumurii*, present only in Cham 1, exhibited the highest relative abundance. This result supported the habitat specialist hypothesis (Magura et al. 2004). In other cases, species richness was negatively correlated with altitude but no relationship was found between altitude and the Shannon–Wiener index  $H'$  ( $R^2 = 0.1543$ ). These results are, in part, in agreement with previous works on altitudinal gradients and terrestrial isopod diversity which reported a tendency of species richness to decrease with altitude in the mountains of Greece (Sfenthourakis 1992; Lymberakis et al. 2003; Sfenthourakis et al. 2008). Furthermore, the sparsity of species in Cham 3, 4, 5 and 6 (mixed forests) and in Bouh 3 is the result of many factors, namely altitude, dryness, mixed forests with conifers and degree of degradation. The explanation for the low diversity observed in mixed forests of Aleppo and *Juniperus* is that isopods are generally in need of  $Ca^{2+}$  to build up their exoskeleton. This suggestion is supported by the high diversity in the open steppe of *Stipa* and *Rosmarinus* in Chambi Park and the reforestation of *Eucalyptus* and *Acacia* in Bouhedma Park.

The temporal distribution of isopod assemblages studied by analyses of similarity between samples and based on the abundance of species exhibited three major groups whose distribution showed a

clear seasonal pattern. Similar distribution patterns for isopods have been reported in other studies (i.e. Hamaïed-Melki et al. 2011; Khemaïssia et al. 2012, 2016). The high relative abundance of representative species recorded in spring may be a consequence of the increased surface activity of the adults which are looking for a sexual partner or the gravid females seeking shelter for their descendants in this period (Dangerfield & Hassall 1994). Moreover, the comparison of species composition among habitats based on altitude and plants assemblages allowed for the identification of three habitat groups: the first (Cham 1) dominated by halophilous vegetation, the second composed of the remaining habitats in Chambi Park and the third including the habitats in Bouhedma Park. CCA summarized the overall situation concerning the abundance of specimens for each species and habitat and confirmed the previous two results. Indeed, according to CCA, the altitude, plant assemblage and soil type are the most frequently reported factors in determining the distribution and composition of terrestrial isopods. For instance, several studies concluded that isopods were highly influenced by variations in habitat structure (Davis 1984). Additionally, the community composition of isopods was linked to the degree of openness of the habitat (David et al. 1999).

Compared to Achouri et al. (2008a,b), Hamaïed-Melki et al. (2011), Khemaïssia et al. (2012, 2016) and Taiti and Rossano (2015), the number of isopod species recorded here, eight species in each park, is lower than that found in humid regions in North Africa. Thus, in the Kroumirie region (northwestern Tunisia) Hamaïed-Melki et al. (2011) found 11 species of terrestrial isopods in the Wadi Moulabouterfess area, and in the Berkoukech catchment area, Achouri et al. (2008a) collected 12 species belonging to five families. However, in the supralittoral zones of wetlands, 13 species were recorded (Khemaïssia et al. 2012). More recently, studies conducted on the diversity of terrestrial isopods around the wetlands revealed a higher species richness (20 species) (Khemaïssia et al. 2016). Further away, in the Oued Laou basin, in the Rif area of northeastern Morocco Achouri et al. (2008b) and Taiti and Rossano (2015) collected 20 and 34 species, respectively. In the Wadi Tahaddart catchment area of northwestern Morocco, Hamaïed et al. (2013) identified 18 species belonging to six families. Even farther away, on the north shore of the Mediterranean, in five mountains in Greece, 13 species were collected across 1000 m, 14 species were found at elevations above 1600 m in Tymphi (northwestern Greece), 16 species were found within 1700 m and 11 species were found across 2300 m (Sfenthourakis 1992).

Finally, our results show that Bouhedma and Chambi, located in arid regions, host characteristic species such as *H. reaumurii* and *P. albinus* that are the dominant component of the arthropod macrodecomposer guild in certain habitats. These species have developed specific adaptations to the arid environment that enhance their survival and reproduction, such as finding shelter from the extreme heat and dryness in burrows. Usually collected in sites linked to human activities, the occurrence of *P. pruinus* and *P. laevis* is affected by the presence of adjacent motels and other buildings which are favorable habitats for such synanthropic species. Finally, small-sized species such as *A. lentus* and *L. panzerii* can find shelter in small crevices and similar places, almost regardless of the general characteristics of the habitat.

### Acknowledgements

The authors would like to thank Professor Abdelkader Ben Rhouma (English Inspector, Ben Arous) for improving the English language.

### Funding

The present study was funded by the Laboratory of Biocology and Evolutionary Systematics (UR11ES11), Faculty of Science of Tunis, University of Tunis El Manar.

### Disclosure statement

No potential conflict of interest was reported by the authors.

### References

- Abdallah F, Noumi Z, Touzard B, Ouled Belgacem A, Neffati M, Chaieb M. 2008. The influence of *Acacia tortilis* (Frossk) Subsp. *raddiana* (Savi) and livestock grazing on grass species composition, yield and soil nutrients in arid environments of south Tunisia. *Flora* 203:116–125.
- Achouri MS, Charfi-Cheikhrouha F. 2002. Biologie et dynamique de population de *Porcellionides sexfasciatus* (Crustacea, Isopoda, Oniscidea). *Comptes Rendus Biologies* 325:605–616.
- Achouri MS, Charfi-Cheikhrouha F. 2009. Albinism and polychromatism in some species of woodlice from Mediterranean regions (Isopoda, Oniscidea). *Crustaceana* 82:1045–1056.
- Achouri MS, Charfi-Cheikhrouha F, Marques JC. 2002. Biology, population and field-growth rates of *Porcellionides pruinus* (Brandt, 1833) (Isopoda, Oniscidea) at Garat Naam (Kasserine, Tunisia). *Crustaceana* 75:1241–1262.
- Achouri MS, Hamaied S, Charfi-Cheikhrouha F. 2008a. The diversity of terrestrial isopoda in the Berkoukech area, Kroumerie, Tunisia. *Crustaceana* 81:917–929.
- Achouri MS, Medini-Bouaziz L, Hamaied S, Charfi-Cheikhrouha F. 2008b. Diversity of terrestrial isopods at the Oued Laou region (North-East of Morocco). *Travaux Institut Scientifique Rabat (Maroc)* 5:75–79.
- Aljatlouai AA, Nair GA. 1994. Breeding and population biology of *Armadillo officinalis* (Isopoda: Oniscidea) of Benghazi Libya. *Journal of Arid Environment* 27:241–255.
- Arcangeli A. 1932. Escursione geologica all'oasi di Marrakech nell'Aprile 1930. Isopodi terrestri [Geological excursion to the oasis of Marrakech in April, 1930. Land isopods]. *Bolletino di Zoologia* 3:225–231.
- Baker MB. 2004. Sex biased state dependence in natal dispersal in desert isopods, *Hemilepistus reaumurii*. *Journal of Insect Behavior* 17:579–598.
- Baker MB. 2005. Experience influences settling behavior in desert isopods, *Hemilepistus reaumurii*. *Animal Behavior* 69:1131–1138.
- Caruso D, Di Maio MC. 1990. Revisione delle specie maghrebine del gen. *Porcellio* Latr. II. Due specie nuove di *Porcellio* del Marocco (Crustacea, Isopoda, Oniscoidea). *Animalia* 17:201–208.
- Chaieb M, Boukhris M. 1998. Flore succincte et illustrée des zones arides et sahariennes de Tunisie. Tunisie: Edition ATPNE, Sfax. pp. 290.
- Charfi-Cheikhrouha F, El Gtari M. 2008. Structure et distribution des Arthropodes de deux plages méditerranéennes: Aouchtane au Maroc et Berkoukech en Tunisie. In: Bayed A, Ater M, editors. Du Bassin versant vers la mer: analyse multidisciplinaire pour une gestion durable. Travaux Institut Scientifique Rabat (Sér. Gén.) 5:93–98.
- Clarke KR, Warwick RM. 1994. Change in marine communities: an approach to statistical analysis and interpretation. 2nd ed. Plymouth Marine Laboratory, UK: Natural Environment Research Council.
- Colombini I, Chaouti A, Fallaci M, Gagnarli E, Scapini F, Bayed A, Chelazzi L. 2008. An assessment of sandy beach macroinvertebrates inhabiting the coastal fringe of the Oued Laou river catchment area (Northern Morocco). In: Bayed A, Ater M, editors. Du bassin versant vers la mer: Analyse multidisciplinaire pour une gestion durable. Travaux Institut Scientifique Rabat (Sér. Gén.) 5:81–91.
- Dangerfield JM, Hassall M. 1994. Shelter site use and secondary sex ratios in the woodlice *Armadillidium vulgare* and *Porcellio scaber* (Crustacea: Isopoda). *Journal of Zoology* 233:1–7.
- David JF, Devernay S, Loucougaray G, Le Floch E. 1999. Below-ground biodiversity in a Mediterranean landscape: Relationships between saprophagous macroarthropod communities and vegetation structure. *Biodiversity Conservation* 8:753–763.
- Davis RC. 1984. Effect of weather and habitat structure on the population dynamics of isopods in a dune grassland. *Oikos* 42:387–395.
- Dollfus A. 1896. Les isopodes terrestres du nord de l'Afrique, du Cap Blanc à Tripoli (Maroc, Algérie, Tunisie, Tripolitaine). *Mémoire Société Zoologique France* 9:523–553.
- Fraj M, Charfi-Cheikhrouha F, Souty Grosset C. 2010. Terrestrial isopods diversity related to irrigation and agricultural practices in the Northeast of Tunisia. *Anadolu Journal of Agricultural Sciences* 25(S-3):217–223.
- Fraj M, El Gtari M, Charfi-Cheikhrouha F. 2008. Density and distribution of burrows of the desert isopod *Porcellio albinus* in two habitats of the Kebili region (Tunisia). In: Zimmer M, Char-Cheikhrouha F, Taiti S, editors. Proceedings of the International Symposium on Terrestrial Isopod Biology: ISTIB-07. Aachen: Shaker Verlag. pp. 113–116.
- Gadeau De Kerville H. 1909. Liste méthodique des espèces, sous espèces, et variétés d'animaux recueillis en Kroumirie (nord-ouest de la Tunisie). Baillière, Paris. pp. 49–51.

- Hamaied S, Achouri MS, Charfi-Cheikhrouha F. 2013. Terrestrial Isopod diversity in the Wadi Tahaddart catchment area (N-W Morocco). *Vie et Milieu - Life & Environment* 63:159–168.
- Hamaied S, Charfi-Cheikhrouha F. 2007. Description d'une nouvelle espèce du genre *Armadillidium* (Isopoda, Oniscidea) de Tunisie. *Crustaceana* 80:523–532.
- Hamaied-Melki S. 2008. Systématique, distribution géographique et écologie du genre *Armadillidium* en Tunisie (Crustacés, Isopodes, Oniscidea). Tunis: Ph. D. Thesis, Université El Manar. 190 pp.
- Hamaied-Melki S, Achouri MS, El Aroui O, Bohli D, Charfi-Cheikhrouha F. 2011. Terrestrial isopod diversity in the wadi Moula-Bouterfess catchment area (Kroumirie, north-west of Tunisia). *African Journal Ecology* 49:31–39. DOI:10.1111/j.1365-2028.2010.01227.x.
- Hotea R, Tomescu N, Muresan D, Hotea M. 2003. Cercetari faunistice si ecologice asupra izopodelor terestre de pe versantul sudic al Muntilor Gutai. *Analele Universitatii din Oradea. Fascicula Biologie* 10:33–37.
- Kheirallah AM. 1980. Aspects of the distribution and community structure of isopods in the Mediterranean coastal desert of Egypt. *Journal of Arid Environment* 3:69–74.
- Khemaissia H, Jelassi R, Souty-Grosset C, Nasri-Ammar K. 2012. Diversity of terrestrial isopods in the supralittoral zone of Ghar El Melh lagoon (Tunisia). *African Journal Ecology* 51:348–357.
- Khemaissia H, Touihri M, Jelassi R, Souty-Grosset C, Nasri-Ammar K. 2016. Diversity of terrestrial isopods in the northern Tunisian wetlands. *African Journal Ecology*. DOI:10.1111/aje.12337.
- Kremen C, Colwell RK, Erwin TL, Murphy DD, Noss RF, Sanjayan MA. 1993. Terrestrial arthropod assemblages: Their use in conservation planning. *Conservation Biology* 7:796–808.
- Kruskal JB, Wish M. 1978. *Multidimensional Scaling*. Beverly Hills, CA: Sage Publications. pp. 93.
- Linsenmair KE. 1984. Comparative studies on the social behaviour of the desert isopod *Hemilepistus reaumurii* and of a *Porcellio* species. *Symposium Zoology Society of London* 53:423–453.
- Linsenmair KE. 2007. Sociobiology of terrestrial isopods. In: Duffy JE, Thiel M, editors. *Evolutionary ecology of social and sexual systems*. Oxford: Oxford University Press. pp. 339–364.
- Lopes ERC, Mendonça MS, 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, De Araujo PB, Hornung E, Schmalfuss H, Taiti S, Szlavecz K, editors. *The Biology of Terrestrial Isopods*, V, *Crustaceana Monographs* 2:217–230.
- Magura T, Tóthmérész B, Molnár T. 2004. Changes in Carabid beetle assemblages along an urbanization gradient in the city of Debrecen, Hungary. *Landscape Ecology* 19:747–759.
- Massa R, Ingegnoli V. 1999. Biodiversità, estinzione e conservazione. Torino: UTET. pp. 518.
- May RM. 1975. Patterns of species abundance and diversity. In: Cody ML, Diamond JM, editors. *Ecology and Evolution of Communities*. Cambridge, MA: Harvard University Press. pp. 81–120.
- Medini L, Charfi-Cheikhrouha F. 1998. Redescription et répartition géographique de *Porcellio variabilis* Lucas, 1846 (Isopode, Oniscoïde) en Tunisie. *Crustaceana* 71:833–844.
- Medini L, Charfi-Cheikhrouha F. 2001. Une nouvelle espèce de *Porcellio* (Crustacea, Isopoda, Oniscidea) en Tunisie. *Zoosystema* 23:59–63.
- Medini-Bouaziz L, El Gtari M, Hamaied S, Charfi-Cheikhrouha F. 2017. Population dynamics and reproductive aspects of *Porcellio albinus* (Isopoda, Oniscidea) of Zarat (Gabès, Tunisia). *Invertebrate Reproduction & Development* 61:18–26. DOI:10.1080/07924259.1263242.
- Medini-Bouaziz L, El-Gtari M, Charfi-Cheikhrouha F. 2015. Reproductive traits of *Porcellio variabilis* Lucas, 1946 (Isopoda, Oniscidea) from Tunisia. *Open Life Sciences* 10:505–513. DOI:10.1515/biol-2015-0052.
- Medini-Bouaziz L, El-Gtari M, Hamaied S, Charfi-Cheikhrouha F. 2016. Spatial distribution of the burrows of *Porcellio albinus* in the coastal area of Zarat (Gabès, Tunisia). *Ethology, Ecology and Evolution* 29:280–291. DOI:10.1080/03949370.2016.1161665.
- Medini-Bouaziz L, Montesanto G, Charfi-Cheikhrouha F, Lombardo BM. 2006. Genetic and morphological analysis of Tunisian populations of *Porcellio variabilis* Lucas (Crustacea, Isopoda, Oniscidea). *Italian Journal of Zoology* 73:173–178. DOI:10.1080/11250000600679991.
- Messina G, Montesanto G, Pezzino E, Caruso D, Lombardo BM. 2011. Diversity of terrestrial isopods in a protected area characterized by salty coastal ponds (Vendicari, Sicily). *Journal of Natural History* 45:35–36.
- Mureşan D, Tomescu N, Olariu L, Hotea R. 2003. Cercetări faunistice și ecologice asupra izopodelor terestre din sectorul mijlociu al Bazinului Arieşului. *Analele Universității din Oradea, Fascicule de Biologie* 10:27–32.
- Nakamura A, Proctor H, Catterall C. 2003. Using soil and litter arthropods to assess the state of rainforest restoration. *Ecology Management and Restoration* 4:20–28.
- Nasri K, Juchault P, Mocquard JP, Souty-Grosset C. 1996. Reproduction saisonnière chez *Hemilepistus reaumurii* (Audouin, 1826), Isopode terrestre des zones semi-arides. *Crustaceana* 69:224–235.
- Nasri K, Morgan E. 2005. Preliminary observations on the natural variation in the endogenous rhythm of the desert Isopod *Hemilepistus reaumurii*. *European Journal of Soil Biology* 41:63–68. DOI:10.1016/j.ejsobi.2005.09.005.
- Paoletti, MG, Hassall M. 1999. Woodlice (Isopoda: Oniscidea): Their potential for assessing sustainability and use as bioindicators. *Agriculture Ecosystem Environment* 74:157–165.
- Pielou EC. 1966. The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology* 13:131–144.
- Rezig M, Nasri K. 1992. Remarques morphologiques et anatomiques sur le Porcellionide *Hemilepistus reaumurii*, présent dans la région de Kairouan. *Revue Faculté des Sciences de Tunis* 5 (série D):13–31.
- Schmalfuss H. 1984. Eco-morphological strategies in terrestrial isopods. *Symposium Zoological Society of London, London* 53:49–63.
- Sfenthourakis S. 1992. Altitudinal effects on species richness of Oniscidea (Crustacea; Isopoda) of three mountains in Greece. *Global Ecology and Biogeography* 2:157–164.
- Sfenthourakis S, Anastasiou I, Strutenschi T. 2005. Altitudinal terrestrial isopod diversity. *European Journal of Soil Biology* 41:91–98.
- Sfenthourakis S, Vasiliki O, Anastasiou I. 2008. A comparative study of isopod assemblages of elevated habitats on five mountains of Peloponnisos peninsula (Greece). In: Zimmer M, Charfi-Cheikhrouha F, Taiti S, editors. *Proceedings of the International*



- Symposium of terrestrial isopod Biology. Germany: Shaker Verlag. pp. 13–19.
- Shachak M, Yair A. 1984. Population dynamics and rôle of *Hemilepistus reaumuri* (Audouin & Savigny) in a desert ecosystem. Symposium of Zoological Society of London 53:295–314.
- Shannon CE, Weaver W. 1963. The mathematical theory of communication. Urbana, I: Illinois University press.
- Souty-Grosset C, Corre S, Freyssinel G, Aubert V, Donque V, Raimond R. 2008. Diversity of terrestrial isopods and habitats in Poitou-Charentes (western France). In: Zimmer M, Charfi-Cheikhrouha F, Taiti S, editors. Proceedings of the International Symposium of Terrestrial Isopod Biology (ISTIB07). Herzogenrath, Germany: Shaker Verlag. pp. 21–37.
- Taiti S, Rossano C. 2015. Terrestrial isopods from the Oued Laou basin, north-eastern Morocco (Crustacea: Oniscidea), with descriptions of two new genera and seven new species. Journal of Natural History 49:2067–2138. DOI:10.1080/00222933.2015.1009512.
- Ter Braak Cajo JF. 1986. Canonical correspondence analysis: A new Eigenvector Technique for Multivariate Direct Gradient Analysis. Ecology 67:1167–1179.
- Tomescu N, Bogdan H, Peter VL, Covaciu-Marcov SD, Sas I. 2008. Terrestrial isopods from the western and north-western Romania. Studia Universitatis Babeş-Bolyai. Biologia 53:3–15.
- Tomescu N, Ferenti S, Teodor LA, Covaciu-Marcov SD, Cicortlucaci AS, Sucea FN. 2011. Terrestrial isopods (Isopoda, Oniscoidea) from Jiului Gorge National Park, Romania North-Western. Journal of Zoology 7:277–285.
- Vandel A. 1956a. Description d'une nouvelle espèce d'*Armadillidium* (*A. pardoi* sp. nov.), provenant du Rif (Crustacés; Isopodes terrestres). Bulletin du Muséum national d'histoire naturelle Paris, 2e Série 28:533–536.
- Vandel A. 1956b. Sur un nouveau sous-genre de *Metoponorthus* et son intérêt biogéographique (Crustacés; Isopodes terrestres). Revue Française d'Entomologie 23:21–30.
- Vandel A. 1958a. Les isopodes terrestres du Rif. Tamuda 6:127–134.
- Vandel A. 1958b. Sur une nouvelle espèce d'*Armadillidium* provenant du Rif marocain, *A. djebalensis* sp. nov. (Crustacés; Isopodes terrestres). Bulletin du Muséum national d'histoire naturelle Paris, 2e Série 30:291–293.
- Vandel A. 1958c. Les Porcellions du groupe atlantique et du sous-groupe bético-rifain. Bulletin du Muséum national d'histoire naturelle Paris, 2e Série 30:443–453.
- Vandel A. 1962. Isopodes terrestres, 2. Faune de France 66:417–931.
- Vilisics F, Solymos P, Hornung E. 2007. A preliminary study on habitat features and associated terrestrial isopod species. In: Tajovský K, Schlahamerský J, Pižl V, editors. Contributions to Soil Zoology in Central Europe II. České Budojovice: ISB BCAS CR, v.v.i. pp. 195–199. ISBN 978-80-86525-08-2.
- Vilisics F, Solymos P, Nagy A, Farkas R, Kemencei Z, Hornung E. 2011. Small scale gradient effects on isopods (Crustacea: Oniscidea) in karstic sinkholes. Biologia, Section Zoology 66:499–505.
- Zaafouri MS, Akrimi N, Flore C, Le Foc'h E, Pontanier R. 1994. Les plantations sylvo-postorales en Tunisie présaharienne. Sècheresse 4:265–275.
- Zavattari E. 1934. Prodrroma della fauna della Libia. Crustacea. Pavia Tip Coop 12:128–139.