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3 authors, including:

Wahiba Zaabar
University of Tunis El Manar

Achouri Mohamed Sghaier
University of Tunis El Manar

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ORIGINAL ARTICLE

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Diversity of terrestrial isopod species in the Chambi National Park (Kasserine, Tunisia)

Mouna Khila | **Wahiba Zaabar** | **Mohamed Sghaier Achouri**

Department of Biology, Faculty of Sciences of Tunis, S11UR11 Bio-Ecology and Evolutionary Systematics, University of Tunis El Mana, Manar II, Tunisia

Correspondence
Mouna Khila
Email: khilamouna@yahoo.fr

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Abstract

Diversity of terrestrial isopods across habitats and altitude was studied in the National Park of Chambi (central Tunisia). Samples were collected over five years in seven sites (S1–S7), within an altitudinal range from 750 to 1,500 m a.s.l. Twelve species belonging to five families were identified, with one endemic species (*Porcellio djahizi*) to this area, and three species were present in all sites (*P. djahizi*, *Leptotrichus panzerii* and *Armadillidium tunisiense*). Agnaridae represented by *Hemilepistus reaumurii* species was the most abundant family (58.77%) and found in only one site. Our results showed differences in species richness between sites. Indeed, S2 and S3 (900 and 1,050 m) showed the highest species richness with 11 species each. This result validates the hypothesis of mid-elevational richness peak and contradicts the theory of large sampling regimes in determining the relationship between species richness and elevation. Terrestrial isopod species richness in the Chambi Mountain tends to decrease with altitude: 11 species in S2 and S3 to four species in S7. The highest Shannon–Wiener diversity index value was observed in S2 ($H' = 3.21$ bits). Canonical correspondence analysis revealed that *H. reaumurii* was positively correlated with temperature whereas *A. tunisiense* and *P. djahizi* were the only species positively correlated with altitude.

Résumé

Nous avons étudié la diversité des isopodes terrestres dans divers habitats et à différentes altitudes dans le Parc National de Chambi, au centre de la Tunisie. Les échantillons furent collectés pendant cinq ans sur sept sites (S1-S7), entre 750 et 1 500 m d'altitude. Nous avons identifié 12 espèces appartenant à 5 familles, dont une espèce endémique de la région (*Porcellio djahizi*) et trois espèces qui étaient présentes sur tous les sites (*Porcellio djahizi*, *Leptotrichus panzerii* et *A. tunisiense*). Les *Agnaridae*, représentés par *Hemilepistus reaumurii*, étaient la famille la plus abondante (58,77%) et ne se trouvaient que sur un site. Nos résultats ont montré des différences de richesse en espèces entre les sites. En effet, S2 et S3 (900 et 1,050 m) avaient la plus grande richesse avec 11 espèces chacun. Ce résultat valide l'hypothèse d'un pic de richesse à moyenne altitude et contredit la théorie des grands échantillonnages pour déterminer la relation entre richesse en espèces et altitude. La richesse en espèces d'isopodes terrestres sur le mont Chambi tend à diminuer avec l'altitude, passant de 11 espèces en S2 et S3 à 4 espèces en S7. La plus grande valeur de l'Indice de diversité de Shannon-Wiener a été observée en S2 ($H' = 3,21$). L'analyse canonique des correspondances a révélé que *H. reaumurii* était positivement lié à la température alors que *A. tunisiense* et *P. djahizi* étaient les seules espèces positivement liées à l'altitude.

KEYWORDS
altitudinal gradient, arid region, diversity, Oniscidea, protected area

1 | INTRODUCTION

The conservation of soil biodiversity became an important aim of international environmental policies, as highlighted in the EU Soil Thematic Strategy (2006), the Biodiversity Action Plan for Agriculture (European Commission, 2001), the Kiev Resolution on Biodiversity (UNECE, 2003) and the Message from Malahide (European Commission, 2004), that laid down the goals of the 2010 Countdown. Oniscidean communities are considered among the most important groups of soil fauna, particularly of the decomposers community (Herrick, 2002; Wolter, 2001), as they are playing a crucial role in soil ecology (Quadros & Araujo, 2008). In addition, they are a food source for a variety of animals (Sunderland & Sutton, 1980; Van Sluys, Rocha, & Souza, 2001). As macrodecomposers, they significantly contribute to detritus processing (comminution, inoculation) and nutrient release (Zimmer, Kautz, & Topp, 2003) and they occur also in extreme habitats, such as salt marshes, arid grasslands and deserts (Hornung, Szlavecz, & Dombos, 2015). Therefore, a good knowledge of isopod fauna is crucial for both community ecology and conservation (Achouri, Medini-Bouaziz, Hamaïed, & Charfi-Cheikhrouha, 2008; Hornung, Vilisics, & Sólymos, 2008; Schmalfuss, 1998).

The diversity of terrestrial isopods has been the subject of several studies (Antonovic, Brigic, Sedlar, Bedek, & Sostari, 2012; Dias, Sprung, & Hassall, 2005; Garcia, 2008; Messina, Montesanto, Pezzino, Caruso, & Lombardo, 2011; Messina, Pezzino, Montesanto, Caruso, & Lombardo, 2012; Messina et al., 2014). Nevertheless, isopod communities inhabiting mountains have not received much attention. The first study of mountainous isopod communities was thus of Schmalfuss and Ferrara (1982) for Mt Cameroon (Africa). More recently, Ferenti, Sas-Kovács, Cupsa, and Ianc (2012) reported that the mountain zone at the north-west of Romania is one of the most intensively studied regions. Patterns of Oniscidea species diversity along elevation gradients on three mountains of continental Greece were examined by Sfenthourakis (1992), Sfenthourakis, Anastasiou, and Strutenschi (2005) and Sfenthourakis, Orfanou, and Anastastiou (2008). Despite the variety of the country's biotopes and climatic regions that could provide important sources of terrestrial isopod biodiversity (Achouri, Medini-Bouaziz, et al., 2008), few studies have focused on isopod diversity of Tunisia (Achouri, Hamaïed, & Charfi-Cheikhrouha, 2008). The reproductive behaviour, systematics and geographic distribution of certain genera in Tunisia have been studied, such as *Hemilepistus* (Nasri, Juchault, Mocquard, & Souty-Grosset, 1996), *Armadillidium* (Hamaïed & Charfi-Cheikhrouha, 2007; Jeriri & Charfi-Cheikhrouha, 2003), *Porcellio* (Ghemari, Bouslama, Ayari, & Nasri-Ammar, 2016; Medini-Bouaziz, El-Gtari, & Charfi-Cheikhrouha, 2015; Medini-Bouaziz, El-Gtari, Hamaied, & Charfi-Cheikhrouh, 2016) and *Porcellionides* (Achouri & Charfi-Cheikhrouha, 2005, 2006). Others studies have focused on the biodiversity of terrestrial isopods in cultivated areas (Fraj, Charfi-Cheikhrouha, & Souty-Grosset, 2010) or around wetlands (Khemaissia, Jelassi, Souty-Grosset, & Nasri-Ammar, 2017; Khemaissia, Jelassi, Touihri, Souty-Grosset, & Nasri-Ammar, 2016; Khemaissia, Touihri, Jelassi, Souty-Grosset, & Nasri-Ammar, 2012). However, isopod communities on Tunisian mountains have not received much attention apart from the study of Hamaïed-Melki, Achouri, Aroui, Bohli, and Charfi-Cheikhrouha (2010) in the Kroumirie Mountains, (north-west Tunisia).

The aim of this study was to contribute to the knowledge on mountainous Oniscidea diversity by presenting a checklist of terrestrial isopod species collected on Chambi Mountain and an analysis of their distribution along an altitudinal gradient.

2 | MATERIALS AND METHODS

2.1 | Study area

The study was carried out in the National Park of Chambi (Figure 1) in the Kasserine region (central Tunisia). Chambi National Park (35°12′23″N, 8°40′57″E) is on the highest mountain of Tunisia (peak 1,544 m a.s.l), covering a total of 6,723 ha, and hosts a large number of plants, mammals, birds and butterflies. The area was declared a Biosphere Reserve by UNESCO in 1977 and a National Park since 1980. Chambi National Park belongs to the arid zone that covers three quarters of the country. It has a Mediterranean climate (Daget, 1977). Annual average temperature is 17°C, and annual precipitation is limited to 250 mm in the plain and 500 mm in higher altitudes. A thin snowpack can cover the summit during the winter. The mountain is divided into seven zones according to altitude (750–1,500 m); soil type: zones 1 and 2 were distinguished by sandy loam soil and calcareous soil, respectively; a rendzine ground in zones 3 and 4 and marl soil characterized zones 5, 6 and 7, and plant associations: halophilous characterized only zone 1 while zones 3, 4, 5 and 6 showed Aleppo pine forest. Seven sites, one in each of these seven zones, were studied (Table 1). Air temperature and soil humidity and soil pH were measured at each site in each season.

2.2 | Sampling and processing

Species were collected manually under stones and leaf litter from each site over five years, from 2008 to 2012, in autumn (October), winter (January), spring (April) and summer (July). Sampling was

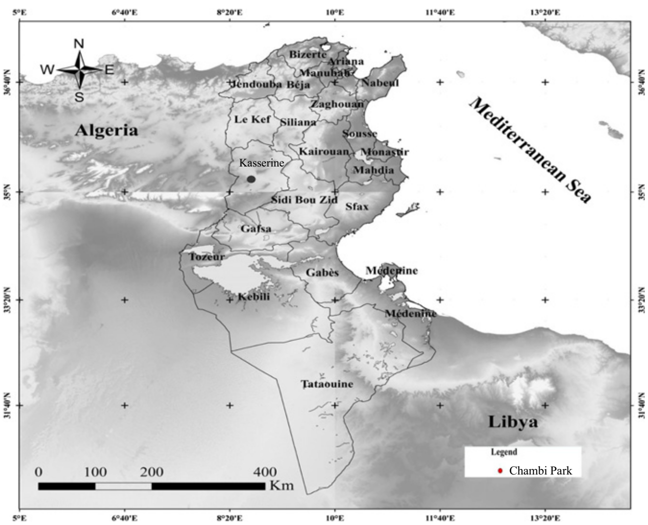

FIGURE 1 The study area: Chambi National Park

made by three persons for half an hour in each site in each season (Souty-Grosset et al., 2008).

Specimens were preserved in 70% ethanol and were identified in the laboratory according to Vandel (1962) under a *Leica MS 5* stereomicroscope.

Seasonal variation in climate and edaphic factors (pH and humidity) was measured in situ using a thermo-hygrometer at each (Table 1).

2.3 | Data analysis

The following parameters were calculated to compare isopod community structure among sites (S1–S7) over the study period (5 years): (i) total species richness (S); (ii) mean of relative abundance; (iii) mean species diversity, using the Shannon–Wiener index ($H' = -\sum p_i \log_2 p_i$) (Magurran, 2003) and (iv) Pielou's evenness index ($J' = H'/\log_2 S$) (Pielou, 1966).

The analysis was performed using PRIMER 5.0 (Clarke & Warwick, 1994). Similarity in communities among sites was calculated using the Bray–Curtis index taking into account the relative abundance (with PRIMER 5.0). The chi-squared test (χ^2) was used to compare diversity parameters (species richness and relative abundance within species groups, families and species occurrence). Canonical correspondence analyses (CCAs) were used to examine relationships between species abundance and environmental factors. Tests were made using the free version of XLSTAT 2011.5.01 software (http://www.xlstat.com).

3 | RESULTS

3.1 | Environmental factors

Slight annual variations in environmental factors were observed between sites. The mean temperature ranged from 18.35% in S6 to 19.47% in S1. Soil pH ranged from 7.85 in S1 to 8 in S7, and humidity from 1.06% in S6 to 2.38% in S3, respectively. However, differences in soil type and plant assemblages were noticed from one site to another. Sandy loam soil and vegetation based on *Atriplex* and other halophytes plants discern S1, whereas S2 was characterized by *Stipa tenacissima* L., *Globularia alypumand* and *Rosmarinus officinalis* with a calcareous soil. S3, S4, S5 and S6 were recognized by an Aleppo pine forest with different soil type: rendzine ground (S2 and S3) and marl soil for (S4 and S5). The same soil type (marl soil) characterized S7, but a different plant assemblage was observed: maquis with evergreen scrubs, *Quercus ilex* and *Pinus halepensis*.

3.2 | Species richness

During the 5 years, a total of 24,770 individuals representing twelve species and five families were collected. Species of the family Agnaridae were the most abundant, represented only by *Hemilepistus reaumurii* (Milne Edwards, 1840) (N = 14,558; Ar = 59%). Porcellionidae (N = 5,785; Ar = 23%) and Armadillidiidae families (N = 3,871, Ar = 16%) were also abundant. The less abundant families (Ar = 1%) were Armadillidae and Platyarthridae [each represented by one species, *Armadillo officinalis* Duméril, 1816

TABLE 1 The characteristics of the sampling sites in the Chambi Park: H % (mean soil humidity); T °C (mean air temperature)

Sites	Altitude (m)	Vegetal characteristics	Soil characteristics	H_{soil} (%)	T_{air} (°C)	pH soil
S1	750	*Atriplex* and other halophytes	Sandy loam soil	1.47	19.47	8.00
S2	900	Stipa tenacissima L., *Globularia alypumand* Rosmarinus officinalis	Calcareous soil	1.21	18.71	7.91
S3	1,100	Aleppo pine (*Pinus halepensis*) forest, Stipa tenacissima and Rosmarinus officinalis	Rendzine ground	2.38	18.76	7.88
S4	1,200	Aleppo pine forest and *Juniperus phoenicea*	Rendzine ground	2.32	18.53	7.96
S5	1,300 m	Aleppo pine forest and *Juniperus oxycedrus*	Marl soil	1.53	18.47	7.96
S6	1,400 m	Aleppo pine forest	Marl soil	1.06	18.35	7.94
S7	1,500 m	Maquis with evergreen scrubs, *Quercus ilex* and *P. halepensis*	Marl soil	1.50	18.38	7.85

(*N* = 306) and *Platyarthrus hoffmannseggii* Brandt, 1833 (*N* = 250)] (Figure 2).

The species found in this study belong to the following categories: North African *H. reaumurii* (Milne Edwards, 1840) (Ar = 59%); *A. tunisiense* Hamaïed & Charfi-Cheikhrouha, 2007 (Ar = 10%); *Armadillidium sulcatum* H. Milne-Edwards, 1840 (Ar = 4.57%) and *Porcellio variabilis* Lucas, 1846 (Ar = 6%), Cosmopolitan: *Porcellionides pruinosus* (Brandt, 1833) (Ar = 2%) and *Porcellio laevis* Latreille, 1804 (Ar = 3%), Mediterranean-Atlantic: *Armadillidium granulatum* Brandt, 1833 (Ar = 2%) and *A. officinalis* Duméril, 1816 (Ar = 1%), Mediterranean: *P. hoffmannseggii* Brandt, 1833 (Ar = 1%), Holomediterranean: *Leptotrichus panzerii* (Audouin, 1826) (Ar = 2%) and *Agabiformius lentus* (Budde-Lund, 1885) (Ar = 1%) and endemic: *Porcellio djahizi* Medini & Charfi-Cheikhrouha, 2001 (Ar = 10%).

Over the five years of sampling, the total number of individuals sampled at each site (altitude) ranged from 7,489 at S1 (750 m) 692 individuals at S6 (Table 2). Total species richness at each site ranged from 11 species at S2 and S3 to four species at S7. At S6 and S7, *P. djahizi* and *A. tunisiense* were codominant, whereas at S5 and S4 codominance was observed between these two species and *P. variabilis*. At S2 codominance was observed between *A. sulcatum* and *P. variabilis*. While *P. djahizi* and *A. tunisiense* were less dominant in the other sites and completely absent at S1, although, a high degree of dominance involved a single species, *H. reaumurii*, at S1 (Table 2). A statistically significant difference in abundance was found between sites using chi-square test (χ^2 = 13.8 df = 6; *p* = .032).

3.3 | Community diversity

The Shannon–Wiener (H′) and Pielou (J′) indices varied from 3.21 to 0.51 and 0.92 to 0.18, respectively (Table 2). The highest values were observed at S2, which was the most diverse site with the most balanced community, where 11 species occur in equal proportions. The least diverse and balanced community was at S1 with seven species occurring in highly unequal proportions due to the massive occurrence of *H. reaumurii*. Hill index showed that S1 is closer to S2 and S3 than to S6 and S7, with the latter two having values close to 1, indicating that they are the least diversified sites (Table 2).

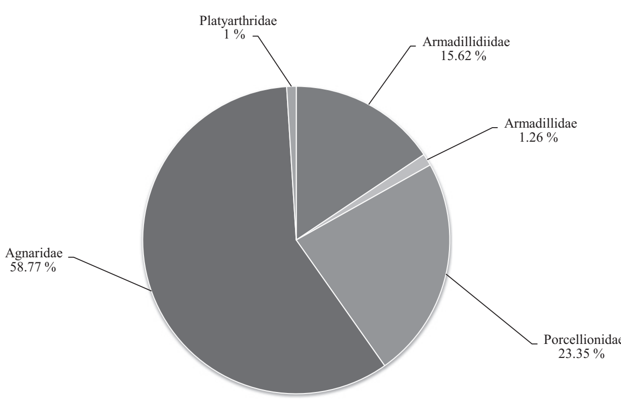

FIGURE 2 Relative abundance (%) for the families sampled

3.4 | Community similarity

According to cluster analysis, the sites were grouped in two main clusters, one formed by S1 (750 m) and the second by all other sites (S2–S7/900–1500 m) (Figure 3). The latter was divided into two subgroups: the first composed by S6 and S7 and the second further divided into two subgroups, S4 with S5 and S2 with S3.

3.5 | Isopod distribution according to altitude and edaphic factors

The results of the CCA are shown in Figure 4. The first and the second axes explain 71.51% and 23.99% of the variance, respectively. The two species, *A. tunisiense* and *P. djahizi*, collected at the more elevated sites (S5, S6 and S7 characterized by marl soil), showed a positive correlation with altitude. These species were negatively correlated with temperature, soil pH and humidity. However, *H. reaumurii*, the most abundant species restricted to S1 distinguished by sandy loam soil was positively correlated with temperature and negatively correlated with altitude. Nonetheless, *P. laevis* and *P. pruinosus*, abundant at lower sites (S1, S2 and S3), exhibited a clear positive association with humidity. The remaining species showed a positive correlation with soil pH and a negative correlation with altitude, humidity and temperature.

4 | DISCUSSION

The Chambi National Park hosts 26% of all terrestrial isopod species (45) recorded in Tunisia (Khemaissia et al., 2017). The majority of collected species have been found in most bioclimatic zones; therefore, most species living on Chambi Mountain seem to exploit different kinds of biotopes (e.g. humid zones, cultivated areas). Species richness on the Chambi Mountain was similar to that found around Tunisian coastal wetland where fourteen species were collected (Khemaissia et al., 2012), six of which (*P. variabilis*, *P. laevis*, *P. pruinosus*, *L. panzerii*, *A. granulatum* and *A. officinalis*) have been found also in the present study. In the Berkoukech area (north-west of Tunisia), 12 species of terrestrial isopods were collected (Achouri, Medini-Bouaziz, et al., 2008), four of which (*P. pruinosus*, *A. sulcatum*, *P. variabilis* and *L. panzerii*) are also present in our study area. Furthermore, 11 species were found in the Oued Moula-Bouterfess catchment area, belongs to the Kroumirie region (Hamaïed-Melki et al., 2010), only two of which (*A. sulcatum* and *P. variabilis*) were also collected on Chambi Mountain. In Majerda agro-ecosystems (Tunisia), only eight species were found (Fraj et al., 2010), five of which (*P. pruinosus*, *A. sulcatum*, *P. variabilis*, *L. panzerii* and *P. laevis*) were collected in the present study. However, the species richness recorded on the Chambi Mountain was lower than that recorded around northern Tunisian wetlands (20 species) (Khemaissia et al.,

TABLE 2 Number of species, and individuals for each sampling site, diversity indices are also reported: (a) Family and isopods species; (b) diversity parameters

Family/species	S1	S2	S3	S4	S5	S6	S7	S1–S7
(a)								
Platyarthridae								
Platyarthrus hoffmannseggii Brandt, 1833	0	22	69	52	107	0	0	250
Porcellionidae								
Agabiformius lentus (Budde Lund, 1885)	0	92	49	35	66	0	0	242
Leptotrichus panzerii Audouin, 1826	123	126	150	34	4	2	2	441
Porcellio laevis Latreille, 1804	520	202	39	0	0	0	0	761
Porcellio variabilis Lucas, 1849	98	343	398	300	248	0	0	1,387
Porcellionides pruinosus (Brandt, 1833)	331	110	6	0	0	0	0	447
Porcellio djahizi Medini & Charfi-Cheikhrouha, 2001;	0	126	443	351	402	569	616	2,507
Armadillidiidae								
Armadillidium granulatum Brandt, 1833	0	247	116	66	41	38	16	524
Armadillidium sulcatum H. Milne Edwards, 1840	53	386	359	224	110	0	0	1,132
Armadillidium tunisiense Hamaïed & Charfi-Cheikhrouha, 2007	8	175	319	297	316	634	466	2,215
Agnaridae								
Hemilepistus reaumurii (Milne-Edwards, 1840)	14,558	0	0	0	0	0	0	14,558
Armadillidae								
Armadillo officinalis Duméril, 1816	0	144	137	21	2	2	0	306
Counts	15,691	1,973	2,085	1,380	1,296	1,245	1,100	24,770
(b)								
Species richness	7	11	11	9	9	5	4	12
Shannon–Wiener index (H′)	0.51	3.21	2.96	2.62	2.49	1.19	1.09	
Pielou's evenness index (J′)	0.18	0.92	0.85	0.82	0.78	0.51	0.54	
Hill (N21)	0.81	0.88	0.88	0.85	0.84	0.93	0.94	

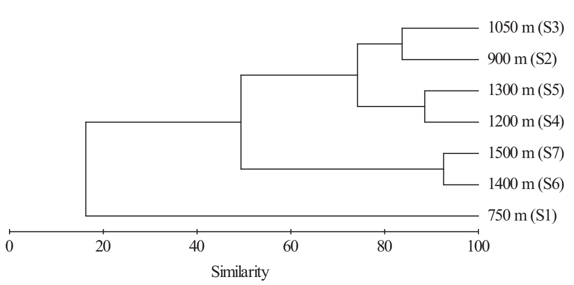

FIGURE 3 Clustering of habitats based on relative abundance of isopod species (Bray–Curtis index, complete linkage)

2017). In Morocco, 18 and 31 species were identified, respectively, in the Wadi Tahaddart catchment area (north-western) (Hamaïed, Achouri, & Charfi-Cheikhrouha, 2013) and in the Oued Laou basin (the Rif area of north-eastern Morocco) (Achouri, Medini-Bouaziz, et al., 2008; Taiti & Rossano, 2015). *Porcellionides pruinosus*, *A. officinalis* and *P. hoffmannseggii*, found in Chambi Mountain, have been collected on many Mountains in Greece (Sfenthourakis, 1992; Sfenthourakis et al., 2005).

The seven studied sites differed in both species composition and abundance. *A. tunisiense* and *L. panzerii* had a wide distribution on Chambi Mountain, as they were collected in all sites. Though, the abundance of *L. panzerii* dropped from 150 specimens in S3 to two specimens in S6 and S7. This latter has a wide geographic distribution in Tunisia, occupying all bioclimatic zones (Hamaïed & Charfi-Cheikhrouha, 2007). While *A. tunisiense* was collected in S1 in very low numbers (N = 8) and with an important number (N = 634 and N = 466), respectively, in S6 and S7. Based on the abundance for each species, we can conclude that these two species do not share the same preferendum (altitude, soil type and plant assemblages).

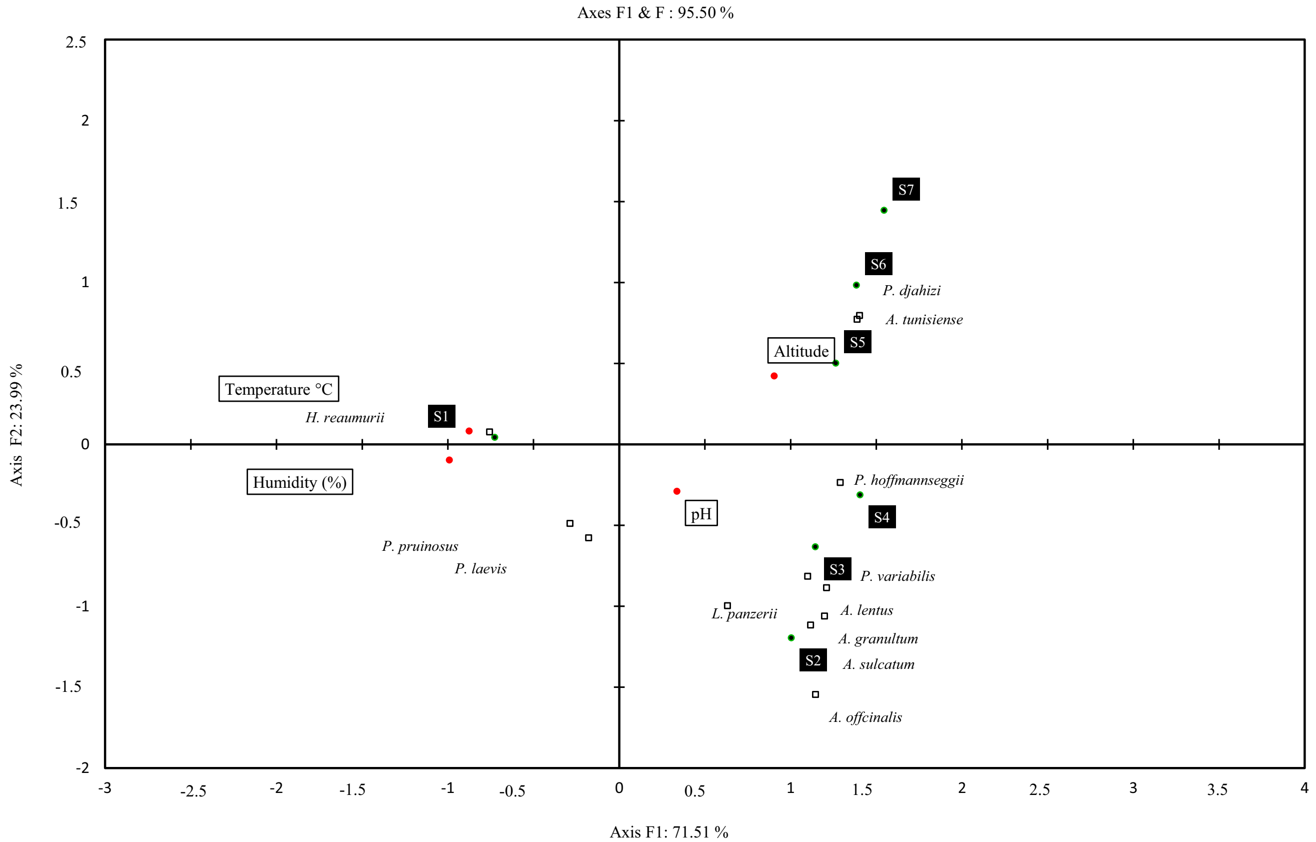

FIGURE 4 Canonical correspondence analysis (CCA) of isopod species, altitude (vegetation association and soil type), air temperature and soil humidity and pH. Abbreviations, S1: site 1; S2: site 2; S3: site 3; S4: site 4; S5: site 5; S6: site 6 and S7: site 7 [Colour figure can be viewed at wileyonlinelibrary.com]

Consecutively, we found *A. granulatum* and *P. djahizi* which were present in all sites except S1. This site is characterized by the halophilous plants and a sandy loam soil. On the other hand, this soil type and plant assemblage are favourable for *H. reaumurii*, which was collected only in S1 (750 m) at a very high abundance (N = 14,558). This excessive density of this species could be explained by its subsocial behaviour and burrow-living that helps it to adapt to harsh environments (Linsenmair, 1985). Thus, the abundance of *P. djahizi* increased with altitude, with 596 and 616 individuals collected at S6 and S7, respectively. These two sites may not have the same plant assemblages, but they share the same soil type (marl soil) and the important altitude (1,400 and 1,500 m). This species is an endemic of the area, with restricted geographic distribution in the arid bioclimatic zone (Medini & Charfi-Cheikhrouha, 2001). Endemism should be higher in mountainous sites due to selective pressures for adaptation to the special temperature and humidity conditions (Sfenthourakis et al., 2005), but in arid regions, mountains might provide more favourable habitats for hygrophilous animals like isopods. Thereby, this latter species show a similar preferendum as *A. tunisiense*, as it was collected with important numbers from the same sites (S6 and S7). *Armadillo officinalis* was found at small numbers (60) showing a preference for relatively humid habitats (Warburg, Linsnmair, & Bercovitz, 1984). The presence of *A. officinalis* on Chambi Mountain, a semi-arid bioclimatic zone known for its severe environmental conditions (Floret & Pontanier, 1982), could be linked to the vegetation cover that creates more favourable microclimatic conditions than those of the open zone (Belsky et al., 1989). *Platyarthrus hoffmannseggii* distribution's depends essentially on their ant hosts (Vilisics et al., 2011) and seemed to prefer the plain and low altitude mountain regions (Vandel, 1962). However, on Mt. Taygetos, Mt. Tymphi (Sfenthourakis, 1992) and on Chambi Mt. this species reaches relatively high altitudes (1,300–1,500 m).

Highest diversity and evenness were recorded in S2 and S3 sites that hosted all species except for *H. reaumurii*. In previous studies in Tunisia, species diversity was found to be related to flora diversity (Achouri, Medini-Bouaziz, et al., 2008). Diversity dropped with altitude: S1 (hosting *H. reaumurii*) was the least balanced site, explaining its separation in the cluster analysis. Decreasing species richness with altitude was also observed by Sfenthourakis (1992) on Greek mountains, Lopes, Mendonça, Bond-Buckup, and Araujo (2005) on Brazil and Schmalfuss and Ferrara (1982) on Cameroon. However, on one Greek mountain, Mt. Panachaiko, species richness did not decline with elevation, probably due to the particular zonation of vegetation on this mountain. In fact isopods prefer open habitats with a mixture of shrubby vegetation more than mono-dominant forests or very dense vegetation (Sfenthourakis et al., 2005). On the other hand, areas with relatively dense vegetation are expected to provide more favourable habitat for isopods as they offer abundant food resources (Hamaïed-Melki et al., 2010).

According to the mid-elevation richness hypothesis (Janzen, 1973; Janzen et al., 1976), essentially demonstrated for insects, species richness should be higher in intermediate elevations, but this pattern of elevation gradient is still controversial. Mid-elevation peaks in species richness have been related to short-term sampling and/or increased disturbance at lower elevations (Janzen, 1973; Janzen et al., 1976). However, not much attention has been given to effects of sampling on elevation gradients (McCoy, 1990). In the current study, Chambi Mountain might validate the hypothesis of a mid-elevation richness peak and contradict the hypothesis of sampling effects in the relationship between species richness and elevation (Wolda, 1987), as we have performed a long-term regular basis sampling for more than five years and we have found the maximum species richness at S2 (900 m; 11 species) and S3 (1,050 m), which can be considered a mid-elevation (Sfenthourakis, 1992).

The CCA showed that only two species, *A. tunisiense* and *P. djahizi*, were positively correlated with altitude. *Hemilepistus reaumurii* appeared to be affected mainly by temperature and to be negatively correlated with altitude, while *P. laevis* and *P. pruinosus* showed a positive correlation with soil humidity. The majority of recorded species seemed to be positively correlated with soil pH. In wetlands, no correlation was found between *P. pruinosus* with soil parameters (Khemaissia et al., 2012). A recent study showed that *L. panzerii* and *A. granulatum* were positively correlated with humidity and soil calcium content (Khemaissia et al., 2017).However, Zimmer and Topp (2000) showed that calcium is sufficiently available in many soils to meet the requirements of isopods and diplopods. Hamaïed-Melki et al. (2010) demonstrated that *A. sulcatum* was negatively correlated with altitude, soil temperature, soil humidity and vegetation but positively with soil pH. Further studies, taking into account more soil parameters (Ca^{2+}, N^{+}, K^{+}, Mg^{2+}, C/N and conductivity), are necessary to identify the relationships between the physicochemical components of the soil, the flora and isopods diversity.

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ORCID

Mouna Khila http://orcid.org/0000-0002-4708-4614
Mohamed Sghaier Achouri http://orcid.org/0000-0001-8628-374X

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