

Diversity and distribution pattern of scorpions from the Ouarsenis massif of Tissemsilt, North-West Algeria

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Abstract. Chedad AW, Ait Hammou M, Chelghoum H, Chedad AS, Ould Amara O, El Bouhissi M, Dahmani W, Sadine SE. 2022. Diversity and distribution pattern of scorpions from the Ouarsenis massif of Tissemsilt, North-West Algeria. *Biodiversitas* 23: 2444-2450. Ecological barriers such as mountains are important factors leading to fragmentation of the range of different species and the important cause of vicariance events. Ouarsenis massif (Tissemsilt, North-West Algeria) is an important protected Park. This paper presents a preliminary study of scorpion diversity and assesses this biodiversity change in this Mountain range along a gradient of many ecological descriptors, including elevation, vegetation cover, slope, and soil types. During 2020 and 2021, we sampled 179 specimens of scorpions by direct hunting from the eight biotopes in Ouarsenis massif. Only adult individuals were used for identification after being killed and kept in 70% alcohol. Based on morphological criteria, we identified eight species distributed in two genera and two families. The family Buthidae was represented by five species with the highest relative abundance (RA) was *Buthus tunetanus* (RA= 47.49%). Furthermore, the family Scorpionidae was represented by three species with the highest RA was *Scorpio maurus* (RA=25.14%). The Shannon index ($H' = 2.71$ bits) indicated that Ouarsenis massif region had a high level of scorpion diversity and the value of evenness ($E = 0.90$) reflected the high equilibrium between the effectiveness of sampled species. The main determinant descriptor of scorpions distribution was the elevation and soil types, while the vegetation cover could be considered an ancillary factor.

Keywords: Algeria, biodiversity, *Buthus*, *Scorpio*, Ouarsenis massif, scorpion

INTRODUCTION

Within the Mediterranean Basin, the biogeography of North Africa is particularly complex because it is situated in highly complex orographic structures, which evolved mainly during the Neogene (Beauchamp et al. 1999; Husemann et al. 2014). This complexity can become the prerequisite for different species' range fragmentation, leading to high biodiversity and many range-restricted and endemic taxa (Hewitt 2011). Moreover, its close affinity with their biotopes (Sadine et al. 2012, 2018; Ouici et al. 2020) represents one of the most important taxa for ecological and biogeographic studies (Schwerdt et al. 2016).

Mountain ranges (elevation and slope) are well-known as the main cause of vicariance events (Rosen 1978; Wiley 1988; Zink et al. 2000) because their structures might act as dispersal barriers (Hewitt 1996). Moreover, bioclimatic zones and seasonal changes could induce a variation in the vegetation cover by its type and density, which plays an

important role in the distribution and density of the scorpion species (Mekahlia et al. 2021).

In Algeria the major studies on scorpions have been carried out in the South part (Lourenço 2002; Sadine 2005, 2012, 2018, 2020, 2021; Idder et al. 2011; Lourenco and Leguin 2011; Sadine et al. 2011, 2014, 2016; Lourenço and Sadine 2014, 2015, 2021; Lourenço and Rossi 2015; Lourenço et al. 2016, 2017, 2018a; Mekahlia et al. 2021; Ythier et al. 2021). While, in the North part, the studies on scorpions remain few and sporadic (Lourenço 2013, 2018a, 2020; Lourenço and Sadine 2016; Abidi et al. 2020; Ouici et al. 2020; Abidi et al. 2021; Touati et al. 2021). However, our study is focused on the scorpion biodiversity of Ouarsenis massif (Tissemsilt, North-West Algeria) during two years (2020-2021) and to assess the biodiversity changes of in this region (eight biotopes) along a gradient of many ecological descriptors including elevation, slope, vegetation covers, and soil types.

MATERIALS AND METHODS

Study area

Our study area is located in the northwestern part of the Ouarsenis massif, Tissemsilt region (Northwestern Algeria) (Figure 1). This forest massif is characterized by a semi-arid to humid climate with an altitudinal gradation ranging from 400-1985m (Bneder 2009). We have selected eight biotopes with distinct plant covers, which are distributed over a height varying between 626 and 1985 m and a slope reaching 50%. The characteristics of these stations are included (Table 1; Figure 2).

Sampling and identification of scorpion

Specimens of scorpions were collected during 2020 and 2021 by direct hunting from the eight biotopes in Ouarsenis massif (Tissemsilt, Northwest Algeria). In this study, only adult individuals are used for identification after being killed and kept in 70% alcohol. Identification was obtained using a stereo-microscope (Zeiss West Germany). Morphological identification was using Vachon (1974). Material is deposited in the Laboratory of Zoology, University of Ghardaia, Algeria.

Data analysis

The exploitation of the results is carried out by the ecological indices of composition, such as the species richness (S): to explain the composition of the scorpion fauna, the relative abundance (RA %): is determined as the ratio of the number of individuals for each species divided over the total number of individuals. Occurrence frequency (Occ) was calculated for each species by the number of stations, wherein the species was found/ the total number of sampled stations. Four species groups are distinguished by Bigot and Bodot (1973) according to their frequencies of occurrence: Very accidental species: an occurrence of less than 10%; Accidental species occurrence varies between 10 and 24%; Common species are present in 25-49%; Constant species are present in 50% and Omnipresent species (Omn) more than 75%. The ecological indices of the structure are also used, such as the values of the index of the diversity of Shannon (H') and Evenness (E) based on the relative density pi of the "i" species (Magurran 2004):

$$H' = - \sum pi \times \log_2 pi$$

$$E = H' / \log_2 S$$

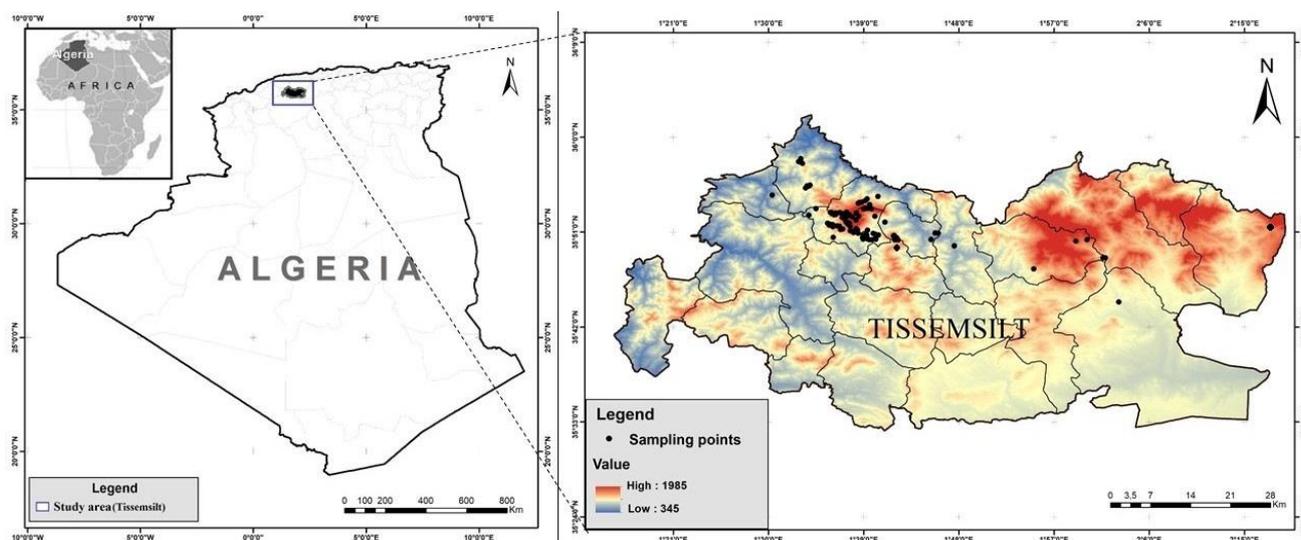


Figure 1. Map of Algeria, showing the sampling points according to Altitude (Ouarsenis massif, Tissemsilt) (map made by: Chedad AW. 2022)

Table 1. Characteristics of sampled biotopes

Biotopes	Elevation (m)	Slope (%)	Plant species	Soil types
Cedar Forest	1200-1650	26.1-46	<i>Cedrus atlantica</i> , <i>Juniperus oxycedrus</i> , <i>Phillyrea angustifolia</i>	Clay-loam
Pine Forest	800-1200	4-34	<i>Pinus halepensis</i> , <i>Juniperus oxycedrus</i> , <i>Cistus monspeliensis</i> , <i>Cistus salvifolius</i>	Limestone-sandy
Mixed Forest 1	900-1300	4.5-17	<i>Pinus halepensis</i> with <i>Juniperu oxycedrus</i> , <i>Quercus ilex</i>	Sandy, decarbonated
Mixed Forest 2	1100-1600	12-49.1	<i>Cedrus atlantica</i> with <i>Quercus ilex</i> , <i>Pinus halepensis</i>	Clay-loam
Maquis	700-1700	6-35.6	<i>Quercus ilex</i> , <i>Juniperus oxycedrus</i>	Schist
Matorral	600-1550	3-42.1	<i>Quercus ilex</i> , <i>Pistacia lentisque</i> , <i>Juniperus oxycedrus</i>	Schist
Grassland	600-2000	2-51	<i>Galicotum spinosa</i> , <i>Genista tricuspidata</i> , <i>Chamaerops humuilis</i>	Clay-loam
Orchard	650-900	12-15.9	<i>Amygdalus communis</i> , <i>Ficus carica</i> , <i>Punica granatum</i>	Schist

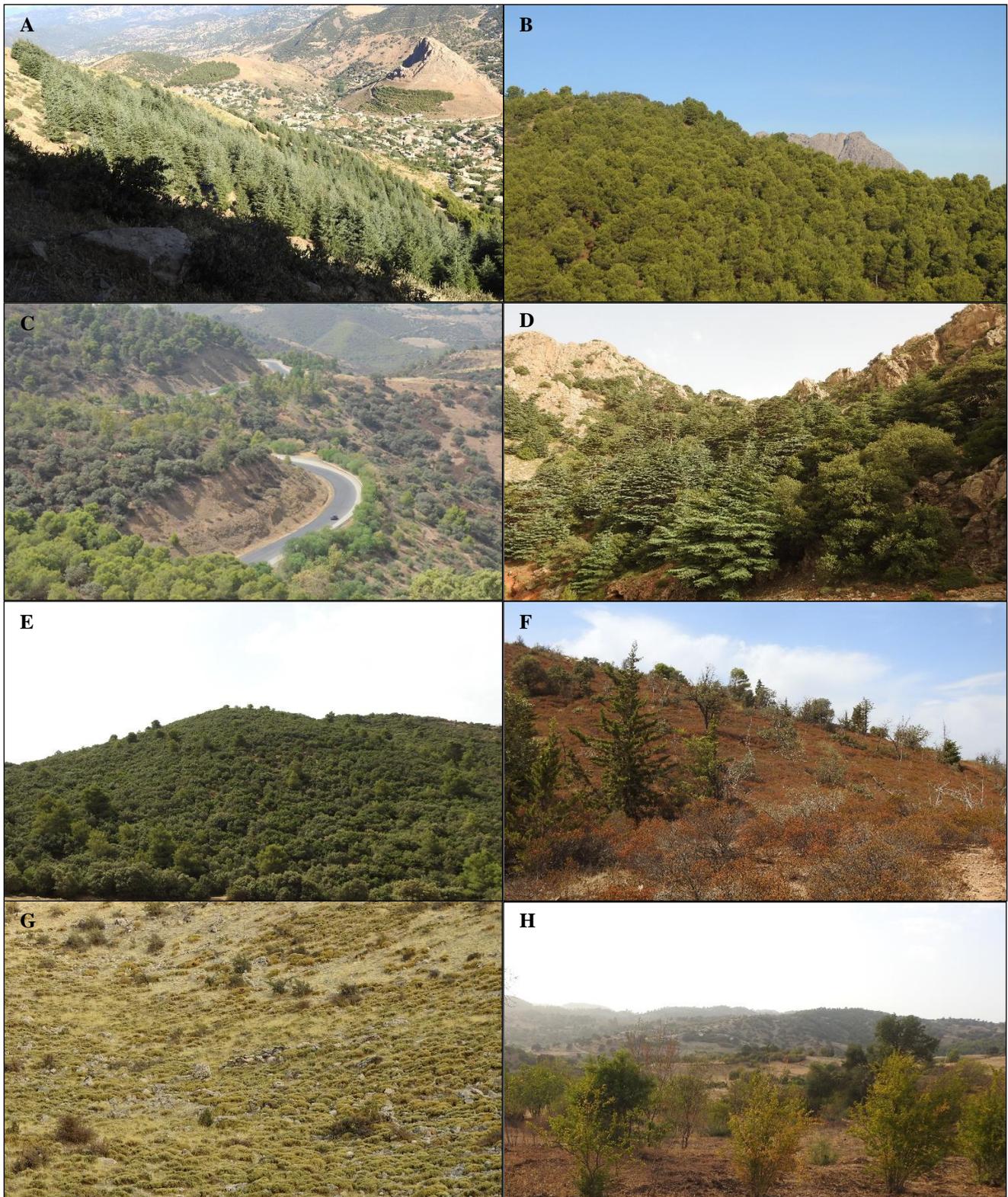


Figure 2. The different biotopes of sampling in the Ouarsenis massif, Algeria. A. Cedar forest, B. Pine forest, C. Mixed forest 1, D. Mixed forest 2, E. Maquis, F. Matorral, G. Grassland, H. Orchard

RESULTS AND DISCUSSION

The relative abundance (RA) and occurrence (Occ)

During the study period between 2020 and 2021, we collected and examined 179 scorpions from Tissemsilt region (North-west Algeria). Based on morphological and morphometric criteria, we have identified 8 species belonging to two genera and two families (Table 2). The genus *Buthus* presented a relative abundance of 62.50% with 5 species, of which, *B. tunetanus* was the most abundant species with a rate of 47.49% and in the second position was *B. paris* with 16.76%. The other species were represented with a very low rate (*B. apiatus*, *B. aures*, and *Buthus* sp.).

In Algeria, the genus *Buthus* represented the most diverse genus with 10 valid species (Ythier et al. 2021). We noted a very evident diversity of this genus in our study region (5 species). Ouici et al. (2020) noted 6 species in the forest of Sidi Bel Abbes region (North-west Algeria). However, only two species of *Buthus* had been reported in Algerian Septentrional Sahara (Sadine et al. 2018), in Algerian North-west (Touati et al. 2021), and in the region of Khenchela and Tebessa, Northeastern Algeria (Hasnaoui et al. 2018; Mekahlia et al. 2021). All previous studies on *Buthus* in Algeria showed that *B. tunetanus* is the most abundant and widespread one (Lourenço and Sadine 2016; Sadine et al. 2016; Lourenço et al. 2018, 2020; Abidi et al. 2021; Chedad et al. 2021; Ythier et al. 2021). *Buthus paris* is mentioned in the east littoral region of Algeria (Abidi et al. 2021; Ythier et al. 2021), but it was represented with the same rate (16.76%) in Sidi Bel Abbes region (North-west Algeria) (Ouici et al. 2020). The low rate of *B. aures* can be justified by the requirement of these species in terms of

climate preference (Arid to Semi-arid) (Mekahlia et al. 2021) and distribution range (Abidi et al. 2020).

The genus *Scorpio* was represented by three species with a dominance of *S. maurus* (25.14%), while *S. punicus* and *Scorpio* sp. were with low percentages 5.03 and 1.68%, respectively. *Scorpio maurus* also was reported as the most abundant scorpion in M'Sila region (Chichi 2015), in Khenchela region (Hasnaoui et al. 2018), and in Sidi Bel Abbes region (Ouici et al. 2020). Among the eight species, *B. tunetanus* was ranked as the omnipresent species. *B. paris* with Occ: 62.5% was classified as the unique constant species in our survey. The category of common species included three scorpions: *B. apiatus*, *S. punicus*, and *Scorpio* sp. Finally, the category of accidental species was represented by two species *B. aures* and *Buthus* sp., i.e., 12.5%.

In North Algeria, many authors reported that *B. tunetanus* as omnipresent species (Hasnaoui et al. 2018; Mekahlia et al. 2021; Ouici et al. 2020). But in M'Sila region, it could be considered as constant species (Chichi 2015). *Buthus paris*, although it was present in 5 stations (constant species), it was in fact, weakly represented by forests. Also, the other species (common and accidental species) are represented by a number not exceeding 3 individuals per station, of which its occurrence frequency had no significance in our study.

Diversity of scorpion

The Shannon diversity index (H') and evenness (E) of scorpion fauna of Ouarsenis massif were calculated by biotopes and in global. The results for these indices are summarized in Table (3).

Table 2. Systematic list and relative abundance and occurrence of scorpion species captured in Ouarsenis massif region (Tissemsilt, North-West Algeria) during 2020-2021

Family	Genus	Species	N	AR (%)	Occ(%)	Scale
Buthidae	<i>Buthus</i> (62.50%)	<i>B. apiatus</i> Lourenço et al. 2020	2	1.12	25	Cmt
		<i>B. aures</i> Lourenço and Sadine 2016	3	1.68	12.5	Acc
		<i>B. tunetanus</i> (Herbst, 1800)	85	47.49	100	Omn
		<i>B. paris</i> (C.L. Koch, 1839)	30	16.76	62.5	Cst
		<i>Buthus</i> sp.	2	1.12	12.5	Acc
Scorpionidae	<i>Scorpio</i> (37.50%)	<i>S. maurus</i> Linnaeus, 1758	45	25.14	75	Omn
		<i>S. punicus</i> Fet, 2000	9	5.03	25	Cmt
		<i>Scorpio</i> sp.	3	1.68	25	Cmt
		Total	2 genera	8 species	179	100

Note: N: Number of individuals, RA (%): Relative Abundance, Occ: Occurrence, Cst: Constant species, Cmt: Common species, Acc: Accidental species, Vac: very accidental species, Omn: omnipresent species.

Table 3. Shannon's index (H') and evenness (E) of scorpion fauna of Ouarsenis massif between 2020-2021

Biotopes	S	N	H'(bits)	Hmax	E
Cedar Forest	2	11	0.44	1.00	0.44
Pine Forest	4	53	1.89	2.00	0.95
Mixed Forest 1	2	15	0.72	1.00	0.72
Mixed Forest 2	5	25	1.81	2.32	0.78
Maquis	4	40	1.56	2.00	0.78
Matorral	3	13	1.42	1.58	0.90
Grassland	4	13	1.74	2.00	0.87
Orchard	3	9	1.22	1.58	0.77
Ouarsenis massif	8	179	2.71	3	0.90

Shannon’s index (H') of the Ouarsenis massif (Tissemsilt. North-West Algeria) was estimated at 2.71 bits. Indicating that this region can be classified as a diversified area with a high equilibrium between the effectiveness of sampled species (E: 0.90). However, this index took values between 0.44 and 1.89 bits in different biotopes. The most important values averages were recorded in Pine forest (1.89 bits) and Mixed Forest 2 (1.80 bits). Then came Grassland with (1.74 bits). The low value of this index was noted in the Cedar Forest (0.44 bits). All evenness (E) reflected a high equilibrium between the effectiveness of sampled species in all biotopes except Cedar Forest when E: 0.44.

The Pine forest was the most diversified (1.89 bits) because it is located at an intermediate elevation (800-1200 m). The same result was found in Sidi Bel Abbes region where the important diversity was between 700 and 1400 m (Ouici et al. 2020). El Hidan et al. (2019) confirmed that the highest richness and abundance of scorpions at a local scale could be found at intermediate altitudes.

Spatial distribution and ecological comments

Like all animal species, the diversity and abundance of scorpions can be influenced by many environmental factors such as the soil type, topography, hydrology, food resources, and especially temperature and precipitation (Polis 1990; Prendini 2005; Dias et al. 2006; Araújo et al. 2010; Sadine et al. 2012; Nime et al. 2013, 2014; Pizarro-Araya et al. 2014). The distribution pattern of scorpions in different biotopes from the Ouarsenis massif is summarized in Figure 3.

Buthus tunetanus shows independence from the studied ecological descriptors (Figure 3). It was collected from all studied biotopes and represented almost half of the specimens collected (47.49 %). This species was mentioned in Morocco, Algeria, Tunisia, and Libya (Sousa

et al. 2017). Widespread one in Algeria (Vachon 1952; Sadine et al. 2012, 2016; Lourenço 2013; Lourenço and Sadine 2016; Lourenço et al. 2018b; Ouici et al. 2020; Sadine et al. 2020; Abidi et al. 2021; Touati et al. 2021; Ythier et al. 2021) and the most abundant scorpion in Ouarsenis massif (Chedad et al. 2021).

Buthus paris was sampled in the majority of medium-altitude biotopes (Pine forest, Maquis, Grassland, and mixed forest 1) except the Cedar forest. This species was recorded in medium and low altitudes in Sidi Bel Abbes region (Ouici et al. 2020). Several works show it affinity to littoral forest in Northeast Algeria and Morocco (Vachon 1952; Lourenço 2013; Touloun et al. 2014; Lourenço and Sadine 2016; Sadine et al. 2016; Lourenço et al. 2018b; Ouici et al. 2020). In Tunisia, *B. paris* was present in the steppes around Le Kef Province, North-West Tunisia (Kovařík 2006). At the northern borders of the Central and Western High Atlas of Morocco, this species occupied an altitude ranging from 900 to 1300m (Touloun 2004; Touloun et al. 2014).

Among the important result of scorpion diversity is the new record of two endemic *Buthus* for Algeria. The first is *B. aures* was found in the mixed forest 2 between, with the dominance of *C. atlantica*, *Q. ilex* and *J. oxycedrus*. It is exactly the same vegetation cover of type locality from Aurès Mountains, Batna (Lourenço and Sadine 2016). The second is *B. apiatus* was found in two different biotopes (forest mixed and Maquis) located between 800 to 1400 m. This species proves its affinity to these environmental conditions of the type locality in the Sidi Bel Abbes region, such as medium altitude (900-1400 m) and vegetation cover with the presence of *P. halepensis* and *Q. ilex* (Lourenço et al. 2020; Ouici et al. 2020). In our study area, only two specimens of *Buthus* have not been identified sampled from Matorral biotope at height elevation (1050 m).

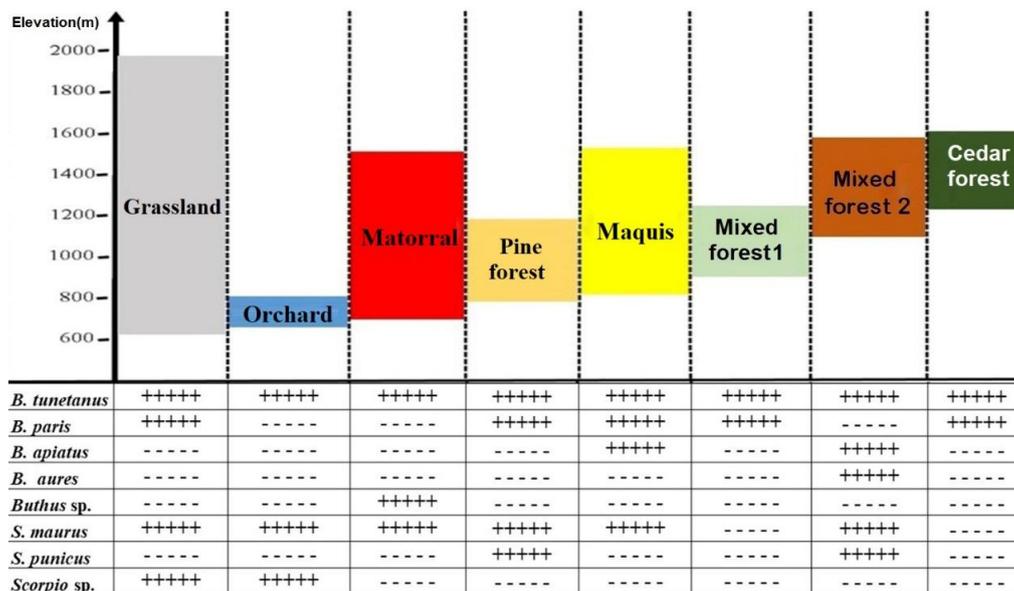


Figure 3. Schema of the distribution of species according to the biotope

Scorpio maurus was sampled from 75% of biotopes (6 biotopes) located between 650 and 1400 m and characterized by an abundance of trees and herbaceous vegetation. We note here, that this species shows a closely affinity to biotopes with herbaceous vegetation and independence to the altitude factor, because it can live in a wide altitude range: from 600 to 1250m in Ouarsenis massif (Ouici et al. 2020; Touati et al. 2021) in medium elevation (900-1100 m) in National Park of Belezma, Batna (Sadine et al. 2012) and Abdel-Nabi et al. (2004) indicated that a subspecies of *S. maurus* able to live at high altitude.

The species *S. punicus* was found in abundance (6 individuals) in Pine forests (900-1100 m) with silt to sandy soils (Table 1). In Algeria, this species was recorded all over northern Algeria (Lourenço and Rossi 2016), at medium altitudes in North-West Algeria (Ouici et al. 2020; Touati et al. 2021). The uncertain *Scorpio* was sampled from two low biotopes (Grassland and orchard). This soil condition seems preferable for all borrowing species. Many authors mentioned that the borrowing scorpion prefers plowed ground and/or sandy soils (Vachon and Kinzelbach 1987; Amr and Abu Baker 2004; Sadine 2018; Ouici et al. 2020).

Finally, and inconclusion, the diversity of ecosystems (8 biotopes) in the Ouarsenis massif (North-West Algeria) leads to a high level of scorpion-specific diversity (8 species; H' : 2.71bits) with the dominance of *Buthus tunetanus* (47.49%). Our survey's important results are the close affinity between scorpions and their biotopes except for *B. tunetanus*, with non-clear affinity to the studied ecological descriptors. While, *B. paris* shows an affinity to medium altitude (900 to 1300m) and low littoral forest. *B. aures* required an arid to Semi-arid climate and vegetation cover with the presence of *P. halepensis* and *Q. ilex*. The borrowing scorpions (*S. maurus*, *S. punicus*, and *Scorpio* sp.) prefer plowed ground and/or sandy soils. Also, we can note that the main determinant of species distribution in this Massif was elevation and soil types when most of the species were found at medium altitudes and in sandy soils. The vegetation cover comes as an ancillary factor of this distribution pattern. Further studies are needed to cover all habitats of this immense mountain and to gain a better understanding of this group. Also, the possibility of finding other species and completing the identification of uncertain species (*Buthus* sp. and *Scorpio* sp.).

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