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ORIGINAL ARTICLE

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

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Ecological barriers such as mountains are among the 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 forest of Atlas cedar (*Cedrus atlantica* M.) and other endemic species. This paper presents a preliminary study of scorpion diversity and assesses of this biodiversity change at this Mountain range along a gradient of many ecological descriptors including elevation, vegetation cover, slope and soil types.

During the two years 2020 and 2021, we sampled more than 179 specimens of scorpions belonging to eight species under 2 genera distributed in 2 families. The family Buthidae is represented by *Buthus tunetanus* (relative abundance "RA"=47.49%), *Buthus paris* (RA=16.76%), *Buthus apiatus* (RA=1.12%), *Buthus aures* (RA=1.68%), and *Buthus* sp. (RA=1.12%). The family Scorpionidae is represented by *Scorpio maurus* (RA=25.14%), *Scorpio punicus* (RA=5.03%), and *Scorpio* sp. (RA=1.68%). The Shannon's index (H'=2.71 bits) indicates that Ouarsenis massif region has a high level of scorpion diversity and the value of evenness (E=0.90) reflects the high equilibrium between the effectiveness of sampled species.

The distribution of scorpions was studied by ecological descriptors when the main determinant of species distribution is the elevation and Soil types. The vegetation cover can be considered as an ancillary factor.

Keywords: Scorpion, *Buthus*, *Scorpio*, Biodiversity, Ouarsenis massif, Algeria.

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 range fragmentation of different species and leading to high biodiversity and many range-restricted and endemic taxa (Hewitt, 2011). Scorpion by its close affinity with their biotopes (Sadine et al., 2012; Sadine et al., 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 a 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; Lourenco and Leguin, 2011; Sadine et al., 2011; Sadine, 2012; Idder et al., 2011; Sadine et al., 2014; Lourenço and Sadine, 2014; Lourenço and Rossi, 2015; Lourenço and Sadine, 2015; Lourenço et al., 2016; Sadine et al., 2016; Lourenço et al., 2017; Lourenço et al., 2018a;

Sadine, 2018; Sadine et al., 2018; Sadine, 2020; Lourenço and Sadine, 2021; Ythier et al., 2021; Sadine, 2021; Mekahlia et al., 2021). While, in the North part, the studies on scorpions remain few and sporadic (Lourenço, 2013; Lourenço and Sadine, 2016; Lourenço et al., 2018b; Abidi et al., 2020; Ouici et al., 2020; Lourenço 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 located in the northwestern part of the Ouarsenis massif, Tissemsilt region (Northwestern Algeria) (Fig. 1), this forest massif is characterized by a semi-arid to humid climate with an altitudinal gradation ranging from 400 m to 1985 m (BNEDER, 2009). In our study, we have selected eight (08) biotopes with distinct plant covers and which are distributed over a height varying between 626-1985 m and a slope reaching 50%. The characteristics of these stations are presented in the Table 1 and Fig. 2.

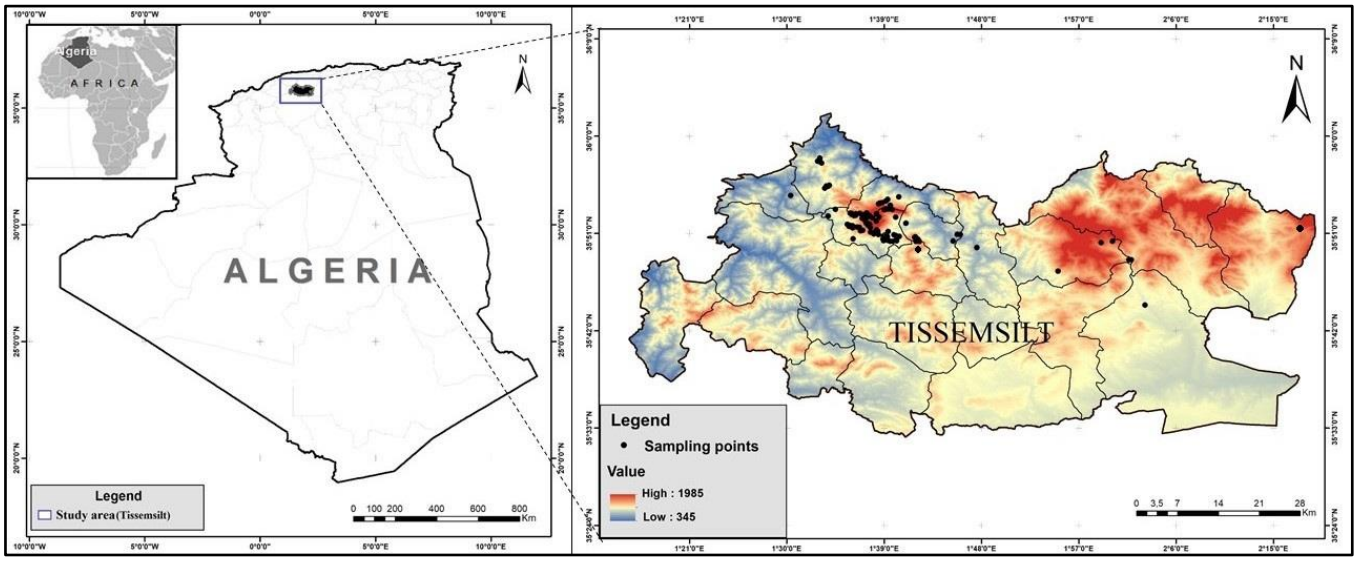

Fig. 1. Map of Algeria, showing the sampling points according to Altitude (Ouarsenis massif, Tissemsilt).

Table 1. Characteristics of sampled biotopes.

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

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

Sampling and identification of scorpion

Specimens of scorpions were collected 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 as described by Vachon (1974). Material is deposited in the Laboratory of Zoology, University of Ghardaïa, 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 %): 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 structure also used such as the values of the index of diversity of Shannon (H'): $H' = -\sum pi \times \log_2 pi$, Evenness (E): ($E = H'/\log_2 S$ based on the relative density pi of the "i" species (Magurran, 2004).

Results and Discussion

The relative abundance (RA) and occurrence (Occ)

During the study period, which runs between 2020 and 2021, we have collected and examined 179 scorpions from Tissemsilt region (North-west Algeria). Based on morphological and morphometric criteria, we have identified 08 species that belong to two families (Table 2).

At Ouarsenis massif, we have sampled 8 scorpion species belonging to two genera *Buthus* and *Scorpio*. The genus *Buthus* present a relative abundance of 62.50% with 5 different species. Of which, *B. tunetanus* is the most abundant species with a rate of 47.49% and in the second position *B. paris* with 16.76%. The other species are represented with very low rate (*B. apiatus*, *B. aures* and *Buthus* sp.).

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	*Buthus* (62.50%)	*B. apiatus* Lourenço, El Bouhissi and Sadine, 2020	2	1.12	25	Cmt
		B. aures Lourenço and Sadine, 2016	3	1.68	12.5	Acc
		B. tunetanus (Herbst, 1800)	85	47.49	100	Omn
		B. paris (C.L. Koch, 1839)	30	16.76	62.5	Cst
		Buthus sp.	2	1.12	12.5	Acc
Scorpionidae	*Scorpio* (37.50%)	*S. maurus* Linnaeus, 1758	45	25.14	75	Omn
		S. punicus Fet, 2000	9	5.03	25	Cmt
		Scorpio sp.	3	1.68	25	Cmt
Total	2 genera	8 species	179	100	/	/

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.

In Algeria, the genus *Buthus* represents the most diverse genus with 10 valid named 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 forest of Sidi Bel Abbes region (North-west Algeria). However, only two species of *Buthus* have been reported in Algerian Septentrional Sahara (Sadine et al., 2018), in Algerian North-west (Touati et al., 2021) and in region of Khenchela and Tebessa, Northeastern Algeria (Hasnaoui et al., 2018; Mekahlia et al., 2021). All studies on *Buthus* in Algeria show that *B. tunetanus* is the most abundant and widespread one (Sadine et al., 2016; Lourenço and Sadine, 2016; Lourenço et al., 2018; Lourenço et al., 2020; Abidi et al., 2021; Ythier et al., 2021; Chedad et al., 2021). *B. 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* is represented by three species with a dominance of *S. maurus* (25.14%). While, *S. punicus* and *Scorpio* sp. with low percentages 5.03 and 1.68%, respectively. The same was reported *S. maurus* was 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* are ranked as omnipresent species. *B. paris* with Occ=62.5% is classified as the unique constant species in our survey. The category common species include three scorpions: *B. apiatus*, *S. punicus* and *Scorpio* sp. Finally, the category of Accidental species is 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; Ouici et al., 2020; Mekahlia et al., 2021). But in M'Sila region it can be considered as constant species (Chichi, 2015).

B. paris, although its present in 5 stations (constant species), it is 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 has no significance in our study.

Diversity of scorpion

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

The value of Shannon's index (H') of the Ouarsenis massif (Tissemsilt. North-West Algeria) is estimated with 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, in different biotopes, this index takes values between 0.44 and 1.89 bits. The most important values averages are 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) reflects a high equilibrium between the effectiveness of sampled species in all biotopes except Cedar Forest when E=0.44.

The Pine forest is 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 that the important diversity was between 700 to 1400 m (Ouici et al., 2020). El Hidan et al. (2019) confirmed that at local scale the highest richness and abundance of scorpion can be found at intermediate altitudes.

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

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 Fig. 3.

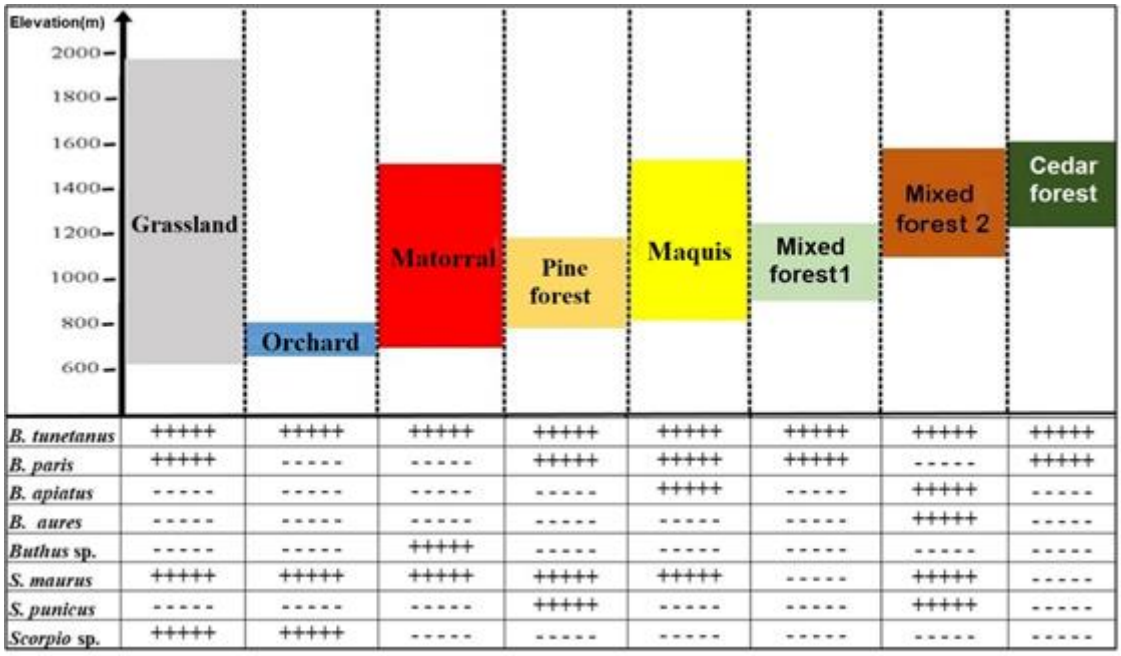

Fig. 3. Schema of the distribution of species according to the biotope.

According to Fig. 3, *B. tunetanus* shows independence to the studied ecological descriptors. it was collected from all studied biotopes and represents 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; Lourenço, 2013; Sadine et al., 2016; Lourenço and Sadine 2016; Lourenço et al., 2018b; Ouici et al., 2020; Sadine et al., 2020; Touati et al., 2021; Abidi et al., 2021; Ythier et al., 2021) and the most abundant scorpion in Ouarsenis massif (Chedad et al., 2021).

B. 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 altitude from Sidi Bel Abbes region (Ouici et al., 2020). Several works shows it affinity to littoral forest in Northeast Algeria and Morocco (Vachon, 1952; Lourenço, 2013; Touloun et al., 2014; Sadine et al., 2016; Lourenço and Sadine, 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 1300 m (Touloun, 2004; Touloun et al., 2014).

Among the important result of scorpion diversity is new record of two endemic *Buthus* for Algeria. The first is *B. aures* was found in the mixed forest 2 between, with 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 type locality in Sidi Bel abbes region such as: medium altitude (900-1400 m) and vegetation cover with presence of *P. halepensis* and *Q. ilex* (Ouici et al., 2020; Lourenço 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).

S. maurus was sampled from 75% of biotopes (6 biotopes) located between 650 to 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 1250 m in Ouarsenis massif (Ouici

et al., 2020; Touati et al., 2020) 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 specimens) in Pine forest (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 altitude in North-West Algeria (Ouici et al., 2020; Touati et al., 2020). The uncertain *Scorpio* was sampled from two low biotopes (Grassland and orchard), this soil condition seems very 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).

Conclusion

The diversity of ecosystems (08 biotopes) in the Ouarsenis massif (North-West Algeria) leads to a high level of scorpion specific diversity (08 species; H'=2.71) with dominance of *Buthus tunetanus* (47.49%). Among the important results of our survey is the close affinity between scorpions and their biotopes except *B. tunetanus* with non-clear affinity to the studied ecological descriptors. While. *B. paris* shows an affinity to medium altitude (900 to 1300 m) and low littoral forest. *B. aures* required an arid to Semi-arid climate and vegetation cover with presence of *P. halepensis* and *Q. ilex*. The borrowing scorpion (*S. maurus*. *S. punicus* and *Scorpio* sp.) prefers plowed ground and/or sandy soils.

Also, we can note that, the main determinant of species distribution is this Massif is elevation and Soil Types, when the majority of 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 to complete the identification of uncertain species (*Buthus* sp. and *Scorpio* sp.).

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