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Spatial relationship between environmental factors and scorpion distribution in Morocco

Moulay Abdelmonaim El Hidan, Oulaid Touloun and Ali Boumezzough

Abstract
The present study aimed firstly, to determine current distribution of sixteen species belonging to three genera (*Androctonus*, *Buthus* and *Hottentota*) in Morocco and their ecological features. Secondly, the significance of the predominant species at any bioclimatic floors, altitude range and soil texture, was discussed. A georeferenced presence-only dataset, comprising 263 point locality records was analyzed with a Geographic Information System (GIS). Study results showed that about 60% of species were present between 0 and 800m. For soil texture, scorpion species were mainly collected in sand-loam-clay (40%) as well as loam soil (30%), with less extent in the sandy soil. While they were scare or absent in Clay-clay-loam texture. According to bioclimate, high mountain climate, humid and sub-humid climate seemed to be less frequented by inventoried species (<10%).
Identification of the environmental factors associated with each scorpion species distribution will allow for determine scorpion envenomation risk and ecological requirement of scorpion species.

Keywords: Scorpions, mapping, bioclimatic floors, altitude, soil texture, Morocco

1. Introduction
Scorpions are the most important taxa of predators in terms of their density and biomass and play a major functional role in ecosystem processes [1]. Distribution of scorpion species at continental or regional scales is associated with areas of climatic, topographic, and geological complexity [2]. At local scales, scorpion distribution is governed mainly by temperature, precipitation, substrate (soil hardness and texture; amount of stone or litter cover) and vegetation physiognomy [3, 4].
Habitat heterogeneity plays an important role in generating biological diversity [5]. Natural ecosystems with strong abiotic and biotic contrasts provide unique opportunities to study the factors controlling the distribution of scorpions. Morocco with its privileged geographical position, its wide geomorphologic variety and very characteristic climates, has resulted in it having the richest scorpion fauna in North Africa. Touloun [6] has indicated that The Moroccan scorpion fauna is known to be the richest and most diversified not only in North Africa but also in the entire Mediterranean circumference. Indeed more than 50 species, belonging to 11 genera and two families (Buthidae and Scorpionidae) are described for the country.
Scorpions are ecologically important in their habitats and have the potential to strongly affect community dynamics and structure, especially among arthropods [7, 8]. Beside the ecological importance of scorpions the importance of knowing the distribution of venomous scorpions, from a medical perspective, is yet another reason to study their distribution and to characterize environmental factors that appear to predict presence or absence of venomous scorpions and envenomation risk.
To analyze some environmental variables affecting the distribution pattern of some species, and also to determinate risk area to establish an efficacy control strategies, Geoprocessing is becoming very important tool [9]. Therefore, we use the geo-graphic information system (GIS) techniques to establish the distribution pattern of species belonging to three genera (*Androctonus*, *Buthus* and *Hottentota*) in Morocco according to many environment factors.

2. Materials and methods
2.1 Study area
Morocco is located on the westernmost tip of North Africa with a surface of 720,000 km2. Characterized by its geography includes no less than four separate mountain ranges, and wide expanses of desert. The three most prominent mountain ranges, which run parallel to each other from the southwest to the northeast, are the Middle Atlas, the High Atlas, and the Anti-

Atlas. The Moroccan coastline, which fronts onto both the Mediterranean and the Atlantic. In the south of the country, the Sahara is the largest desert in the world.

The climate in Morocco is as varied as its diverse geography. In general the country has a Mediterranean climate. The coast has a warm, Mediterranean climate tempered on the eastern coast by southwest trade winds whilst inland areas have a hotter, drier, continental climate. In the south of the country, the weather is very hot and dry throughout most of the year, though temperatures can drop dramatically at night, especially in the months of December and January.

2.2 Scorpion collection and identification

To locate scorpions, the ground was examined by lifting rocks, stones and tree bark. The burrows considered to be occupied by scorpions were destroyed with a shovel to try to dislodge them. For the anthropophilic species, we investigated under stones and near indoor dwellings. The property that renders the scorpion carapace strongly fluorescent under ultraviolet light creates an excellent opportunity to detect these nocturnal arachnids. So, the nocturnal missions were conducted, using portable ultraviolet lamps. Specimens were identified in laboratory using the keys and descriptions published by [10, 11, 12].

In this study we gathered out all point locality data for each species established by our scientific team since 1995 till now. Identified specimens were deposited in the Environment and ecology laboratory (L2E) collections.

2.3 GIS data base and analysis

The input environmental variables used in the GIS analysis (Arc Gis v.10 software) were selected based on their direct/indirect influence on the scorpion's ecology. These variables are: elevation, bioclimatic zone and soil texture. Geographic locations of study sites, we used GPS map 60CSx. accordingly, the following thematic data layers were generated in a PC Arc Info GIS environment:

For the altitude map, we extracted the metadata through the data base of www.Cartograf.fr website, which offers all the geographical maps around the world (Accessed 2009).

After having georeferenced raster image, we created the layer altitudes using ArcMap (Arcgis 10).

For the bioclimatic map, we extracted the metadata from the website of Ministry of Energy, Mines, Water and Environment (2010). To create the layers of maps corresponding to bioclimatic zones we used ArcGIS 10 (http://www.environnement.gov.ma/index.php/fr/bd/bd-onem).

For the soil map, we download the soil map from the Food and Agriculture Organization of the United Nations that covers the study area. Then we converted the FAO classification into type of textures using the table of components; sand, silt, clay and the triangle diagram for determining.

(http://www.fao.org/geonetwork/srv/fr/metadata.show?id=14116).

All thematic data layers were co-registered and the obtained scorpion data were linked to the respective geographic location of study sites as presence of scorpion species. The output is six maps each depicting the distribution of the corresponding factor associated with species of each genus over the whole study area.

3. Results

The present study was focused on sixteen species belonging to three genera *Androctonus* (three species), with one *Hottentota* (1 specie) and *Buthus* (12 species). The choice of these three genera was based on their great distribution in Morocco as well as, they contain species of biomedical interest such as; *Androctonus mauritanicus*, *Androctonus amoreuxi*, *Buthus occitanus* and *Hottentota gentili*.

Seven studied species (*A. gonneti*, *A. maroccanus*, *A. sergenti*, *B. rochati, B. maroccanus, B. barbouri, B. confluens* and *H. franzwerneri*) were located in just one or two stations in the studied area. So we could not study their distribution. For the other species, the geographical distribution was presented according to some environmental variables (Fig. 1, 2, 3 & 4; Table 1 and 2).

Table 1: Number of species localization in each classes of Altitude (m)

	Altitude Classes						
	0-400m	**400-800m**	**800-1200m**	**1200-1600m**	**1600-2000m**	**2000-2400m**	**>2400m**
H.gentili	12	18	13	6	0	4	2
B. paris	3	6	10	4	2	0	1
B. occitanus	6	0	0	0	0	0	0
B. mariefranceae	7	1	0	0	0	0	0
B. mardochei	5	5	0	0	0	0	0
B. malhommei	4	6	1	0	0	0	0
B. lienhardi	0	0	0	1	1	4	3
B. elmoutaouakili	5	2	2	0	0	0	0
B. draa	0	3	5	2	1	1	0
B. boumalenii	0	0	0	4	0	1	0
B. bonito	8	0	0	0	0	0	0
B. atlantis	6	0	0	0	0	0	0
B. albengai	0	2	2	2	0	1	0
A. mauretanicus	11	18	6	0	1	0	0
A. liouvillei	4	3	10	0	0	0	0
A. amoreuxi	7	8	5	3	0	0	0

As shown in (Table 1), scorpion species were collected at all altitudes (from 0 to 2400m) but they were more present between 0 and 800m. *B. bonito*, *B. atlantis* and *B. occitanus* are found mainly at low altitude (between 0 and 800m), while, *B. lienhardi* peaked at higher altitude (upper than 2400m). It should to note that *H. gentili* was found in all classes of altitude stretching between 0 to upper than 2400m but it was more present between 400 and 1200m. Regarding dangerous species known in Morocco such as *A. mauritanicus* and *A. amoreuxi* they were present in sections of altitude between 0 and 1600m but they peaked between 400 and 800m.

When the species number was assessed according to the

altitudinal gradient, scorpion species were found to occupy mostly low altitude and we have shown that there is a negative correlation between the altitude and number of species (r = -0.966; p<0.01).

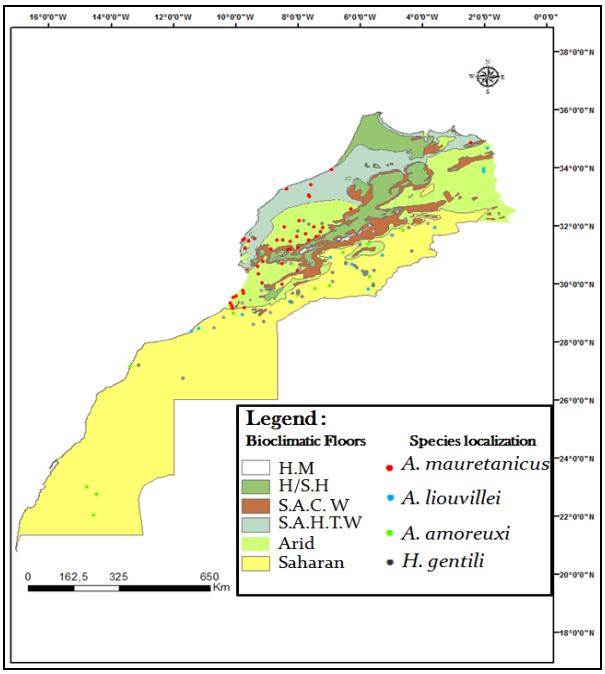

Fig 1: *Androctonus* and *Hottentota* species localization in Morocco by classes of bioclimatic floors. With H.M = High mountain floor, H/S.H=Sub humid and humid bioclimatic floor, S.A.C.W= Semi-arid with cool winter bioclimatic floor, S.A.H.T.W= Semi-Arid with Hot and Temperate Winter.

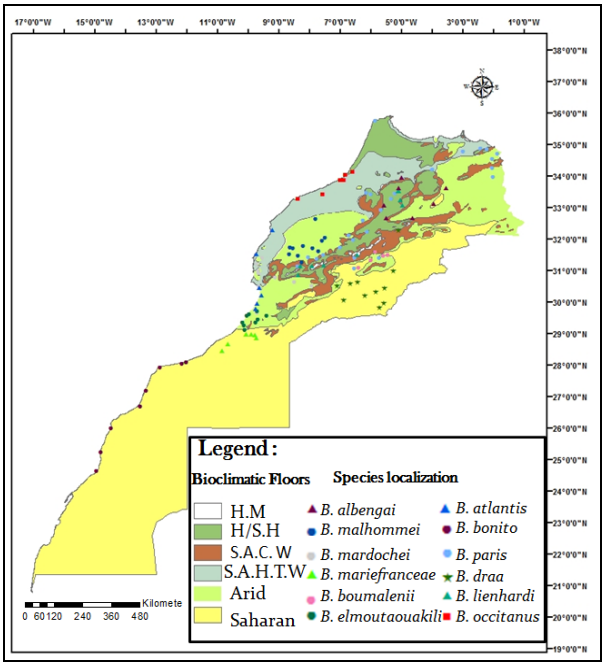

Fig 2: *Buthus* species localization in Morocco by classes of bioclimatic floors. H.M = High mountain floor, H/S.H=Sub humid and humid bioclimatic floor, S.A.C.W= Semi-arid with cool winter bioclimatic floor, S.A.H.T.W= Semi-arid with Hot and Temperate Winter.

According to bioclimate, we collected also all scorpion species studied in all bioclimatic zones. However, high mountain climate and humid and subhumid climate seemed to be less frequented by studied species. In fact we found only one species (*B. lienhardi*) in the high mountain climate, and five in the humid and subhumid climate. Three associations of scorpion faunas were determined (Fig. 1, 2). The first one (*A. amoreuxi, A. liouvillei, B. mariefranceae, B. draa, B. boumalenii, B. bonito* and *H. gentili)* prefer Saharan climate, the second one (*A. mauretanicus B. mardochei, B. malhommei and B. elmoutaouakili*) prefer arid climate, the third one (*B. occitanus, and B. atlantis*) which peaked in semiarid climate with hot and temperate winter. It's important to note that *B. paris* have no bioclimatic preferences. Thus we found it in arid, semi-arid and humid bioclimatic floors.

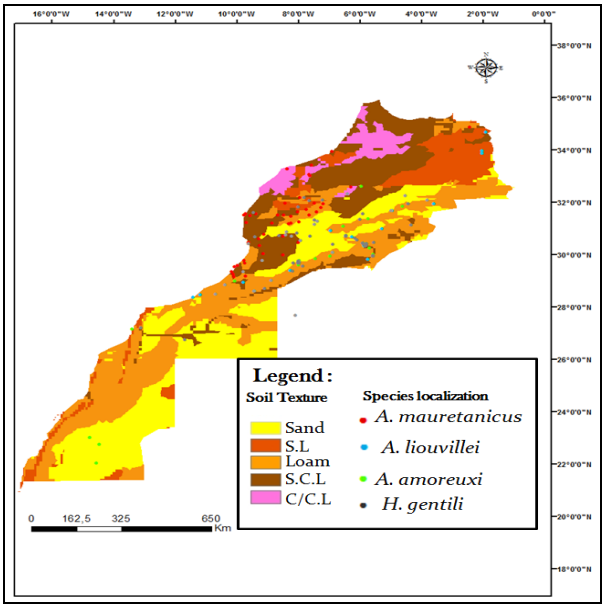

Fig 3: *Androctonus* and *Hottentota* species localization in Morocco by soil texture classes. With S.L = Sand-loam, S.C.L= Sand-Clay-loam and C/C.L= Clay/Clay-loam.

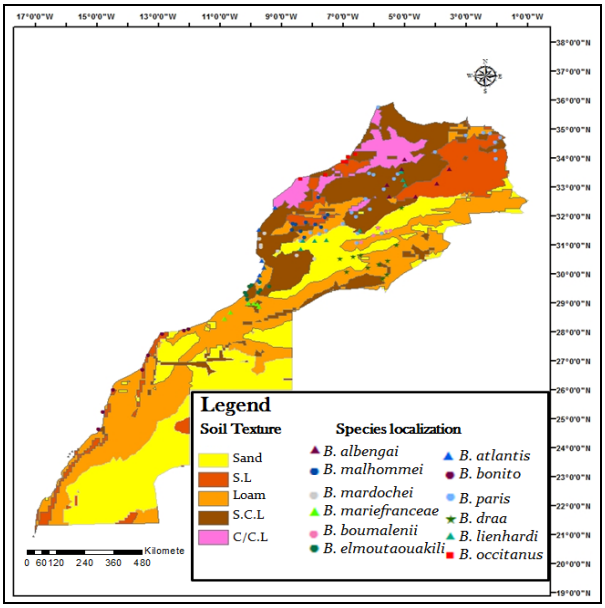

Fig 4: *Buthus* species localization in Morocco by soil texture classes. With S.L = Sand-loam, S.C.L= Sand-Clay-loam and C/C.L= Clay/Clay-loam.

For soil texture, scorpion species were mainly collected in sand-loam-clay as well as loam soil and with less extent in the sandy soil. While they were scare or absent in Clay-clay-loam

texture (Fig. 3 & 4). In fact six species (*A. mauretanicus, B. paris, B. occitanus, B. mardochei, B. elmoutaouakili,* and *B. atlantis*) peaked in sand-loam and clay texture and six species (*B. mariefranceae, B. draa, B. bonito* and *H. gentili*) peaked in loam soil texture. While *A. amoreuxi* and *A. liouvillei* had no preference for soil texture (Table 2).

Table 2: Preference of each species to Altitude (m), Bioclimatic zone and Soil texture.

Species	Soil texture	Bioclimatic floor	Altitude
A. amoreuxi	No preferences	Saharan (82%)	400-800m
A. liouvillei	No preferences	Saharan (87%)	800-1200m
A. mauritanicus	Sand-clay-loam (62%)	Arid (67%)	0-800m
B. albengai	Sand-loam (50%)	No climatic preferences	400-2000m
B. atlantis	Sand-clay-loam (70%)	S.A.H.T.W (70%)	0-400m
B. confluens	Sand-clay-loam (100%)	S.H.H (100%)	400-800m
B. bonito	Sand-Loam (88%)	Saharan (100%)	0-400m
B. boumalenii	Sand (60%)	Saharan (80%)	1200-1600m
B. draa	Loam (53%)	Saharan (82%)	400-1200m
B. elmoutaouakili	Sand-clay-loam (73%)	Arid (100%)	0-800m
B. lienhardi	Sand (50%)	S.A.H.F.W (58%)	Up to 2400m
B. malhommei	Sand-loam (54%)	Arid (91%)	0-800m
B. mardochei	Sand-clay-loam (80%)	Arid (60%)	0-800m
B. mariefranceae	Loam (75%)	Saharan (100%)	0-800m
B. occitanus	Sand-clay-loam (75%)	S.A.H.T.W (100%)	0-400m
B. paris	Sand-clay-loam (44%) & loam (28%)	No climatic preferences	400-1200m
H. gentili	Loam (41%) & sand (39%)	Saharan (51%)	No preferences

In sum, scorpion species occur in a wide range of habitats and individual species have very specific habitat requirements as shown in Table 2.

4. Discussion

To analyze some environmental variables affecting the distribution pattern of some species, we reassembled 262 geographic localization concerning 16 species belonging to three genera (*Hottentota*, *Androctonus* and *Buthus*) as these genera include the most widespread and venomous species known in Morocco for instance, *Hottentota gentili*, *Androctonus mauretanicus*, *Buthus occitanus*.

It's well known that the selection of habitats and distribution of scorpion, as in other animals, is governed by an interaction of various ecological factors. The following sections on soils, climate and topography serve as a summary of available information on these broad ecological factors. In this study we assess the importance of such factors and their possible effects on distribution of 16 scorpion species.

Lamoral [13] had reported that the nature of the substratum, taken in its broadest possible definition, is probably the most important single factor that has and still determines the distribution of scorpions. Actually several scientists had classified scorpions according to their preferred habitats [2]. Moreover Prendini [14] in his study on southern African scorpion species had introduced the concept of substratum-specialization and identified stenotopic vs. eurytopic ecomorphotypes. In the present study, the distribution pattern of the scorpion species studied, suggest that the sixteen species could be divided on 3 classes according to the substratum predilections. *B. occitanus, B. mardochei, B. lienhardi, B. elmoutaouakili* and *B. bonito* are Psammophilous species, which occur mainly in sandy systems. Newlands, Polis and Prendini [14-16] had reported that Psammophilous species display ecomorphological adaptations to increase locomotor and burrowing efficiency in loose sand. Accordingly all psammophilous scorpions are specialists, poorly adapted to life outside their sandy habitats and their distributions are restricted to sand systems [16]. Consequently the narrow distribution of these six species could be explained by their substratum specialization.

Among the listed species, *B. paris*, *B. draa*, *B. boumalenii, B. mariefranceae* and *B. atlantis*, occupy loam or sand-clay-loam texture and may display ecomorphological adaptations to assist with these compacted substrata [14, 16]. Some of these species, e.g. *B. paris*, are widely distributed, presumably because they are able to occur in a greater range of soil texture than is possible for psammophilous species.

The final group, comprise the 3 species of *androctonus* and *Hottentota gentili.* These species are the most geographically widespread and must be considered as habitat generalist species. These species shelter under stones or any other available cover and display few ecomorphological adaptations. The distribution of such species is governed primarily by climate [2].

Beside the substratum, Climate is another ecological factor that affects scorpion distribution. Indeed climate could affects scorpion distribution by two main components; rainfall (relative humidity) and temperature [2]. In fact, Warburg *et al.* [17] had reported that rainfall has a obvious effect on scorpion distribution in Israel, while temperature constitute the main factor limiting the southward expansion of tropical scorpion species on the east coast of Australia [18]. In our study, we have shown that several species are restricted or dominant in one type of bioclimate, thus *A. amoreuxi, A. liouvillei, B. mariefranceae, B. draa, B. boumalenii* and *B. bonito* were dominant in Saharan bioclimate, indicating that these species are adapted to climate with very low rainfall (P <150mm) and hot temperature. While *B. malhommei* and *B. elmoutaouakili* were more adapted to arid bioclimate characterized by low rainfall (150 to 350mm) and high temperature especially in summer.

Altitude is a variable that is frequently related to changes in species richness and community composition [19]. However, altitude not necessarily has an effect on species distribution. Environmental variables that change with altitude may have an effect on community composition [20]. Different studies have been conducted at local scale to assess the effects of altitude on the distribution and diversity of scorpion fauna. These studies had reported that mountain areas are characterized by a decrease in richness and abundance as altitude increases [21], though the highest richness and abundance might not be found at the lowest but at intermediate altitudes [20]. Our data suggest that species richness decrease with altitude. Thus, most of studied species occur mainly in low and intermediate altitude between 0 to

1200m, as well as, there is a negative correlation between the altitude and number of species. However it appears that *B. lienhardi* is a high-altitude specialist and occurs essentially in altitude upper than 2400m.

5. Conclusion

The present investigation is an update of three scorpion genera distribution in Morocco according to many ecological factors (bio-climate, soil and elevation). These results will be taken into consideration to determine scorpion envenomation risk area and to establish an efficacy control strategies.

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