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Fauna and Zoogeography of Scorpions (Arachnida: Scorpions) in Morocco

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ABSTRACT

A nationwide collection and identification campaign since February 2018, which includes 58 collection stations and 12 identification foci in order to map and count scorpion species in Morocco. Scorpion fauna includes nine gender and twenty-nine species of Buthidae, spread throughout the kingdom. Also, one gender and three species of Scorpionidae widespread beyond the northern half of Morocco. The scorpion fauna of Morocco is the most diverse in the south of Europe and the MENA area and rivals that of many other countries.

Key words: *Fauna, Morocco, Scorpions*

Introduction

Scorpions, the most vital taxa of predators, play a key role in regulating processes of the ecosystem Nime *et al.* (2014). The distribution of various scorpion species is majorly correlated with geological complexity, climate, and topography at the continental and regional scales Visser *et al.* (2020). In the regions of Morocco, the distribution of scorpion species is generally dominated by soil texture, hardness, temperature, and vegetation physiognomy Druce *et al.* (2009); Foord *et al.* (2015). They are the ancestral chelicerate arthropods and belong to the class of Arachnida. They have been adapted to various climates and spread by diverse habitats, ranging from humid tropical forests to most arid deserts Polis (1990).

Scorpion envenomation is a general public health issue worldwide. In Morocco, the envenomation problem is severe because of the diversity of the Buthidae scorpion family's gender. The venom of Genus Buthidae, Androctonus, Hottentota, and Buthus is significantly dangerous in southern and central Morocco (Aboumaâd *et al.,* 2014). Various Moroccan areas such as Zagora oases, Moroccan Sahara, and pre-Sahara areas are usually famous for the existence of lethal scorpion species, for instance, *Androctonus liouvillei* (*A. liouvillei*), *Androctonus amoreuxi* (*A. amoreuxi*), and *Hottentotta gentili* (*H. gentili*). The existence of such lethal wildlife may increase the incidences of scorpion envenomation (Abdelmonaim *et al.,* 2017). KELAA DES SRAGHNA, the province of Morocco also famous for having deadly scorpion species, including *Buthus malhommei, Androctonus mauritanicus*, and *Hottentotta franzwerneri* gentili (Hmimou *et al.,* 2008).

Heterogeneity of habitat also has an essential role in developing biological diversity among Morocco's scorpion species Abdelmonaim *et al.* (2017). Natural ecosystems having sturdy biotic and abiotic contrasts regulate the distribution of various scorpions' species. Morocco has the richest scorpion fauna because of its widespread geomorphologic variety, privileged geographical position, and very enig-

matic atmosphere. That's why it is considered that Moroccan scorpion fauna is the richest not only among North Africa but also among the entire Mediterranean circumference, having approximately 50 unique species, associating to 2 families (Scorpionidae and Buthidae) and 11 gender Abdelmonaim *et al.* (2017); Ghalim *et al.,* (2000).

Regarding the genus Androctonus particular, various scorpion species have been naturally characterized from Morocco, for example, *Androctonus mauritanicus, Androctonus sergenti, Androctonus gonneti,* and *Androctonus Liouvillei* (Lourenço *et al.,* 2009). These species have been remained endemic up to now in Morocco. *Androctonus australis* has also been reported from the various regions of Morocco (Geniez, 2009). There are a total of seven species belong to the genus Androctonus that have been reported highly in Morocco: named *Androctonus australis, A. Maroccanus, A. Amoreuxi, A. Sergenti, A. Mauritanicus, A. Liouvillei*, and *A. Gonneti* (Lourenco, 2002 and Lourenço and ang (2012).

The genus Buthus has been considered as complicated and challenging to understand for a long while. Therefore, in 1952, Vachon established a much better definition of *Buthus* genus and transferred its numerous species into another genus Lourenço and (Slimani, 2004). That's how the classification of Buthus genus species was described by the (Vachon, 1952). Particularly Buthus occitanus remained complicated to understand and unsatisfactory due to the presence of various poorly characterized subspecies. Later, a more brief and accurate characterization of Buthus species was endeavored by Lourenco in 2003 to classify various new species and describe few subspecies (Lourenco, 2002).

A. amoreuxi is a yellow straw-colored scorpion that is large in size and could reach approximately 8cm. It is widely distributed all over Africa. A amoreuxi can be found in Morocco also, it has been identified as located in the Draa Valley of Morocco, which is an Anti-Atlas and Tafilalet region. It is recently reported to capture near the Oujda region, the northeast of Morocco (Touloun *et al.,* 2014, 2016. The *A. amoreuxi* and *A. Liouvillei* is mostly found in the dry climate, such as the Saharan climate of Africa. While they do not have any preference for soil texture to living in. This signifies that *A. amoreuxi* and *A. Liouvillei* are modified to live in dry, low rainfall, and hot regions of Morocco (Abdelmonaim *et al.,* 2017).

In southern parts of Morocco, specifically in the regions where people farm the lands, it is considered that the black scorpions are deadly and dangerous. Moreover, it's a traditional belief that the black thing is more dangerous. However, the scientific fact is that the toxicity of scorpion venom is not associated with its color. In fact, various other non-black scorpions are also dangerous and deadly, for instance, *A. australis, B. Occitanus*, *Leiurus quinquestriatus*, have either yellow or brown body color instead of black. The other false belief among Morocco people is that the male scorpion is usually more dangerous as compared to female but scientifically, there is no difference has been observed in the composition of venom between both sexes of scorpion species (Touloun *et al.,* 2001). A gonneti is a dark color scorpion and can be found in the Akka region of Morocco.

Its color can be varied from black-brown to black (Touloun *et al.,* 2016). A gonneti is regularly found in various regions of Morocco, usually, it is well-known to the Anti-Atlas, a new station that is located 800km far from the typical station of the scorpion species (Touloun *et al.,* 2016).

A. mauretanicus is a black scorpion, usually found in the dark places of houses, gardens, cemeteries, and old abandoned buildings. A. mauretanicus also live in burrows left by rodents and lizards. It is considered the most dangerous scorpion species of Morocco and is accountable for the highest number of deadly, often serious envenomings in children (Mahjoubi-Boubaker *et al.,* 2003).

A. mauretanicus is responsible for a significant number of deaths in the southern region of Morocco, and its two subspecies have also been identified in the southern flanks of the High Atlas and the Souss plain of south- western Morocco, known as A. mauretanicus mauretanicus and *A. mauretanicus* bourdoni (Touloun *et al.,* 2001).

B.bonito was discovered from the Tan Tan beach of Morocco, it has been most abundant species of the Atlantic coast to date (Touloun *et al.,* 2016. B. bonito has a yellow straw-colored body with the fifth ringtail and the dark telson Lourenço and and (2012). This scorpion species's habitat is crumbly white sand or the underneath surface of limestone rocks and occasionally they also have been found in a few centimeters' deep burrows (Touloun *et al.,* 2016).

Buthus draa species has been reported to locate in the valley of the Draa River in southern Morocco. Earlier it was misidentified and misunderstood as Buthus Occitanus. Its particular name shows its lo-

cation, the very first region from where it was identified. Its body color is yellow, and its body is covered with dark zones. These dark zones are better marked in female Buthus draa as compared to males (Lourenço and Slimani, 2004).

Scorpio maurus species usually characterized through robust clamps, these clamps are used to dig deepest burrows with oval openings. Its body color is light brown to dark brown and is widely found in the southwestern regions of Morocco. It has further three subspecies: *S. maurus* weidholzi found in the Houz plain; *S. maurus* mogadorensis living in the Atlantic coastline, the Souss plain, the Akka region and, the west extremity of the Western High Atlas. The third subspecies is *S. maurus* fuliginosus, found in High Atlas flanks of southwestern Morocco (Touloun, 1997 and Touloun *et al.,* 2001). *S. Maurus* sting is not deadly and the pain can only be felt on the sting site as compared to other scorpion species. According to the local people or children, pain intensity is similar to that of a honey bee or wasp stings Mebs (2015); Touloun *et al.* (2001).

Materials and Methods

Collection and identification stations

The choice of collection stations was intended to cover the whole country. Some of the stations far from the others because of the climatic conditions and the biotope are extended over several kilometers. Other stations are very close because they have climatic factors and a different biotope. After the designation of 58 collection stations spread throughout the kingdom. 12 identification foci* Table 1 were chosen to determine the gender and species of scorpions, given the difficulty of identifying the samples.

Collecte and Systematic

Collecting scorpions

To locate the scorpions, the ground was checked through lifting stones and tree barks. The places or the burrows considered having a shovel destroyed the scorpions to remove the scorpions. Ultraviolet lamps were used in the fields to carry out the tasks. For the anthropophilic species, we investigated under-stones, burrows and near indoor dwellings. The property that renders the scorpion carapace strongly fluorescent under ultraviolet light creates an excel-

Table 1. Collection stations, Identification Foci and regions

Region	Name	Ref
Béni Mellal - Khénifra	Moulay Bouazza*	36
	Beni Mellal	37
	Arougo	38
Casablanca-Settat	Harbala Forest	27
	Sidi Gharb Forest	28
	El Borouj	31
	Sidi Hajjaj	32
	Said Maachou	33
	Casablanca*	34
	Benslimane	35
Dakhla - Oued Ed Dahab	Bir Gandouz	1
	Tichla	2
	Aousserd	3
	Al Argoub*	4
	Bir Anzarane	5
	Oum Drayga	6
Daraa - Tafilalet	Tazenakht	22
	Kelaat Mgouna*	23
	Alnif	24
	Aoufous	25
	Tafraoute Sidi Ali	26
	Zazate	29
	Boudnib	44
Fes - Meknes	Imouzzer Kander	39
	Timahdite*	40
	Outat El haj	41
	Ghafsai	48
	N Parc Tazekka	49
Guelmim-Oued Noun	Bir Lahlou	9
	Abteh	12
	Assa*	13
	Lakhssas	14
Laayoune - Sakia El Halma	Galtat Zemmour	7
	Boujdour*	8
	Smara	10
	El Hagounia	11
	Marrakech-Safi Ghazoua*	20
	Mejjat	21
Oriental	Sidi Boubker	30
	Tendrara	42
	Figuig*	43
	Taourirt	50
	Ain Beni Mathar	51
	Aghbal	52
	Gourougou Mount	53
Rabat-Salé-Kenitra	Maamora Forest	45
	Moulay Bousselham*	46
	Jorf El Melha	47
Souss-Massa	Tafraoute	15
	Ighrem*	16
	Aoulouz	17
	Foum Zguid	18

Table 1. *Continued ....*

Region	Name	Ref
Tanger-Tétouane-Al Houcima	Erg Chegaga	19
	N Parc Hoceima	54
	N Parc Talassemtane	55
	Jbel Moussa	56
	Cap Spartel*	57
	Archeological Lixus	58

lent opportunity to detect these nocturnal arachnids. Epidemiological data was also be used to determine the locality of the scorpion in the area. The specimens were then taken to the identification foci for further analysis then identified using the taxonomic key.

Taxonomic key

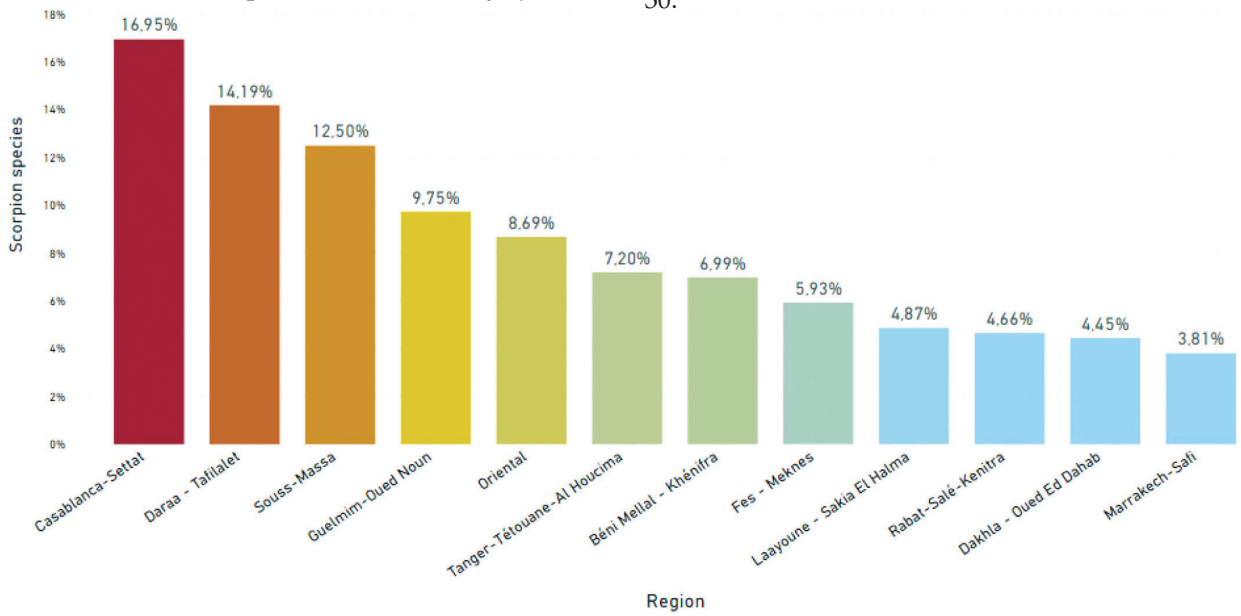
The following authors inspire this Key: Stockwell, Sissom, Francke, Prendini, Fet and soleglad. It's preferred to indicate many complementary features rather than presenting a simplified key. Stockmann and (Ythier, 2010).

1. Sternum triangular or sub-triangular (much wider than at the apex), with a rimmed dimple on the posterior edge. Coxapophyses 1 rounded latero-anteriorly. Telotarse carrying bristles (no spinules). Chelicerae: dorsal edge of the mobile finger with 5 teeth (including 2 basal teeth). Ventral edge of the mobile finger with 2 strong teeth. Fixed finger with 4 dorsal teeth of which the 2 proximal ones always joined together in a fork; 2 dorsal protuberances. Tibial spur present or absent according to genus. Pedipal: trichobothria type *A. Femur* with 10 T including 5 internal *T. Patella* without Ventral *T. Wide* distribution; 9 gender.

Buthidae

All gender of Buthidae have fine or wide claws. The sternum has a slightly enlarged apex in Butheoloides. It can be described in these cases as subtriangular. The genus Buthus has the prosome bearing a "cephalothoracic lyre": the posterior and lateral hulls are extended in a continuous line. The genus Lisothus has a smooth, non-granular prosome. The genus Androctonus has a very strong tail with very protruding laterodorsal hulls. Sometimes, the tail is widened from front to back. The genus Compsobuthus is characterized by the tergal (mesosomal) carinae, which extends rearward beyond the segments' posterior edge. The gender Orthochirus, Butheoloides and Microbuthus have.

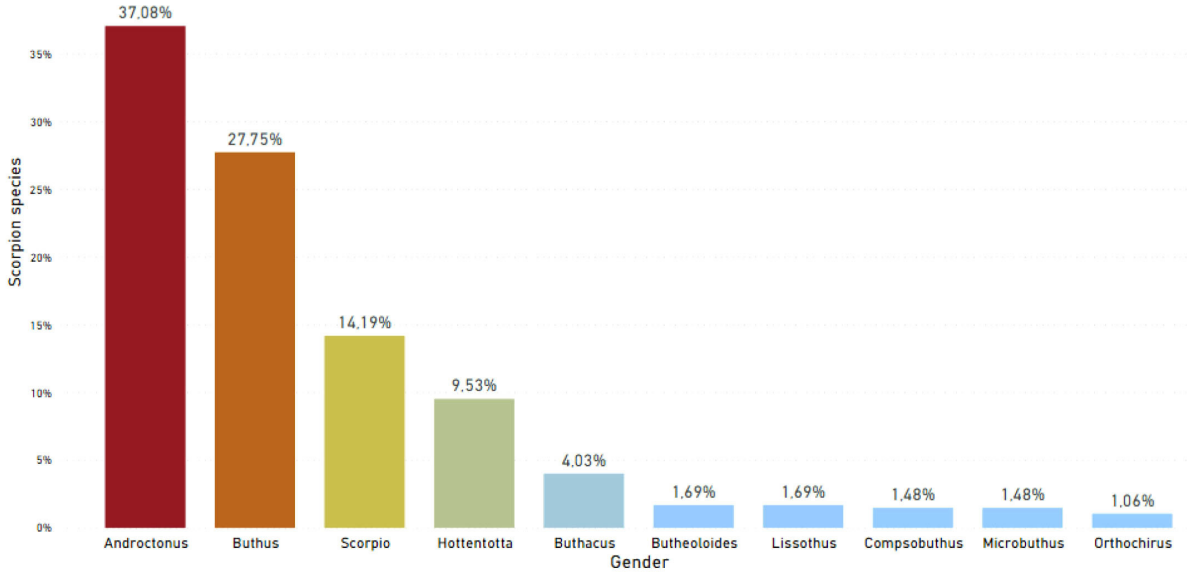
The last rings of the tail punctuated (sunken dots). The genus Hottentota is also cited with weak carapace carinae; the anterior median being almost absent. The dentition on the distal part of the mobile finger of the chela pedipalp presents four-terminal denticles. Metasomal segment I with 12 carinae; II to IV with 10 carinae and V with 7 carinae. The genus Buthacus has 9 rows of granules on the movable finger and the teeth in the pectins are between 25 and 30.



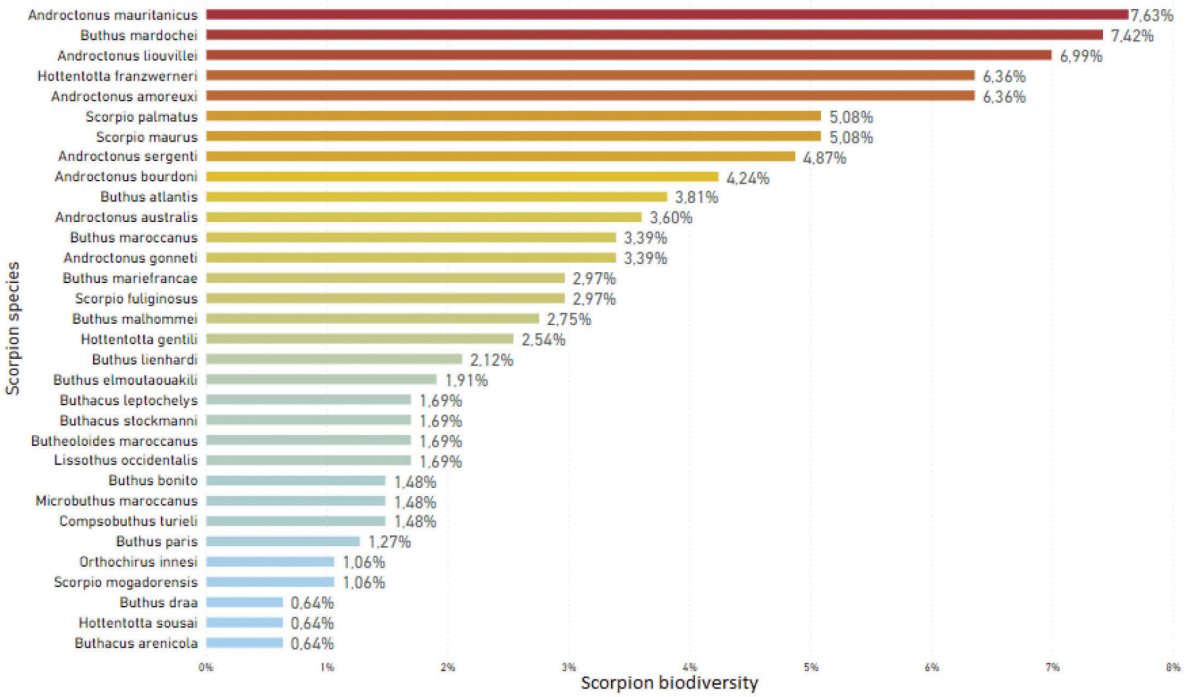
Graph 1. Scorpion biodiversity according to Moroccan region

2.Chelicerae: mobile finger with a ventral edge otherwise shaped (it can be smooth, toothless, crenelated, or have one tooth in subdistal position, or several teeth with or without a ventral serrula). 3

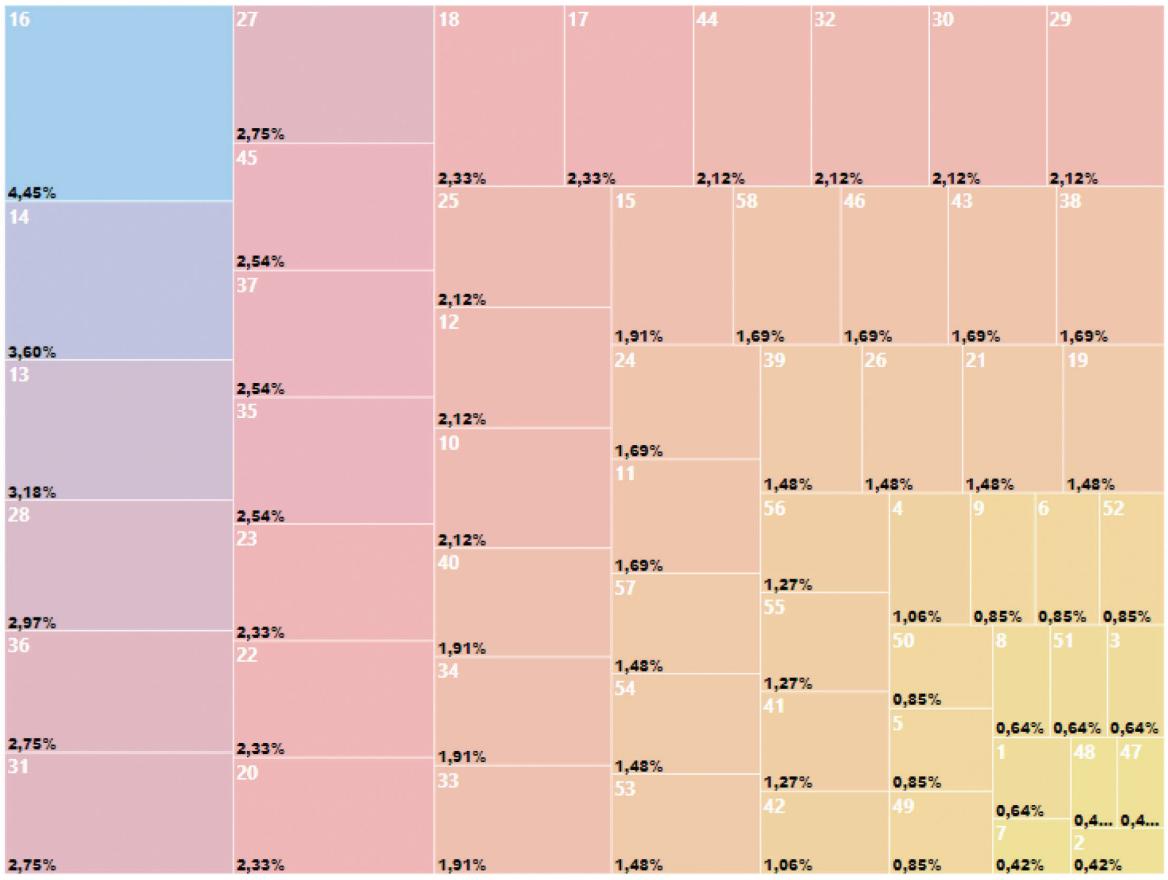
3. Chelicerae: movable finger with the toothed dorsal edge (subdistal not split). Ventral face telotarsus with large base bristles, usually a single basitarsal spur (no internal ba- sitarsal spurs). Movable finger of the chelicerae with the smooth ventral edge. And 2 on the external side of the clamp (not on the ventral side). db on the fixed finger (not on the hand). Wide claws (especially in Scorpioninae). 4. A very accentuated sub-needle tuber. No accentuated sub-needle tuber. 5. Rings 1 to 4 of the tail with 2 submedian. 6 6.3 pairs of side-eyes (except exception). Telotarse with side edges finished in rounded



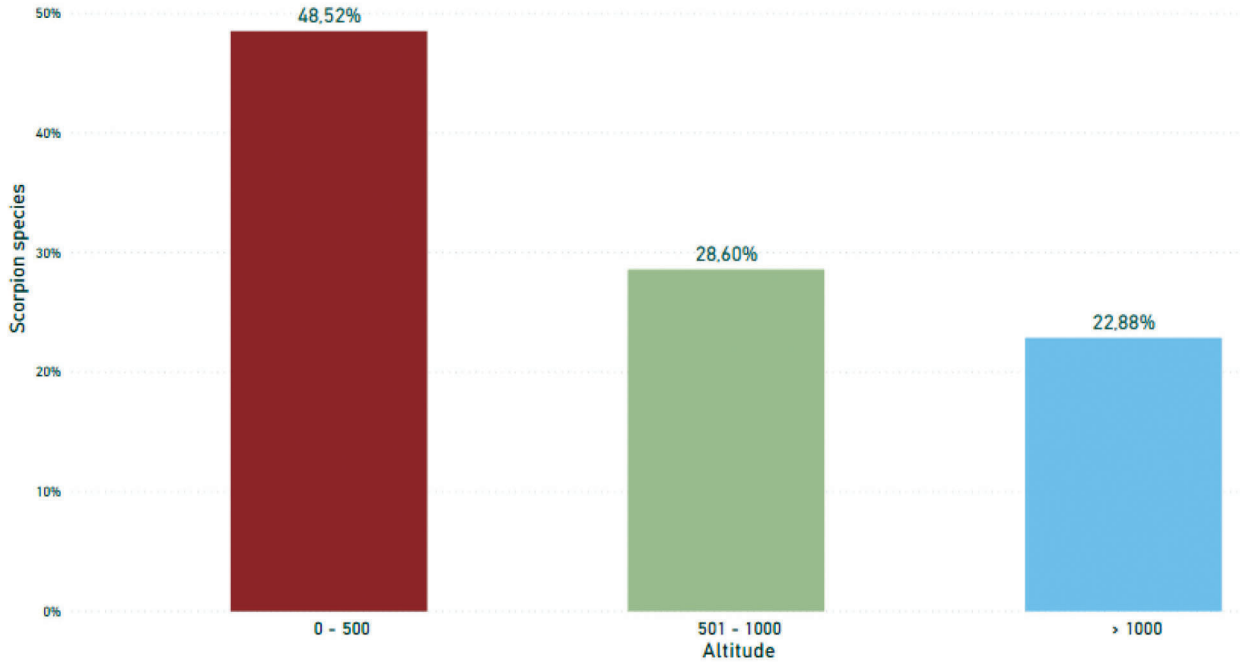
Graph 2. Scorpion biodiversity according to Gender



Graph 3. Scorpion biodiversity according to Species



Graph 4. Scorpion biodiversity according to Station



Graph 5. Scorpion biodiversity according to Altitude

lobes. Raised ocular tuber. Species with strong digging. Scorpionidae, Scorpioninae

The genus Scorpio has the patella with 19 trichobothries and the claw with 25 trichobothries.

Results

After the collection and identification campaign, we have identified 2 families, 10 genders and 31 species of scorpion in Morocco. This is organized as a followup.

The most extensive family by far is the Buthidae family. The most extensive gender is the genus Androctonus, as well as the less responded gender is Orthochirus. Graph 1

The most widely distributed species is *Androctonus mauritanicus*, contrary to the species Buthacus arenicola which has a very low distribution in Morocco. Graph 2

The region where there is high scorpion biodiversity

is the Casablanca-Settat region, as opposed to the Marrakech-Safi region, which comes at the bottom of the list Graph 3.

The station which oversees biodiversity in Morocco is station 16 "Ighrem". At the bottom of the list is station 2 "Tichla". Graph 4.

Regarding the tolerance of scorpion species to altitude, the scorpion species are distributed according to the altitude intervals between 0 and 500 m, between 501m and 1000 m and beyond 1000 m. Graphs 5 and 6.

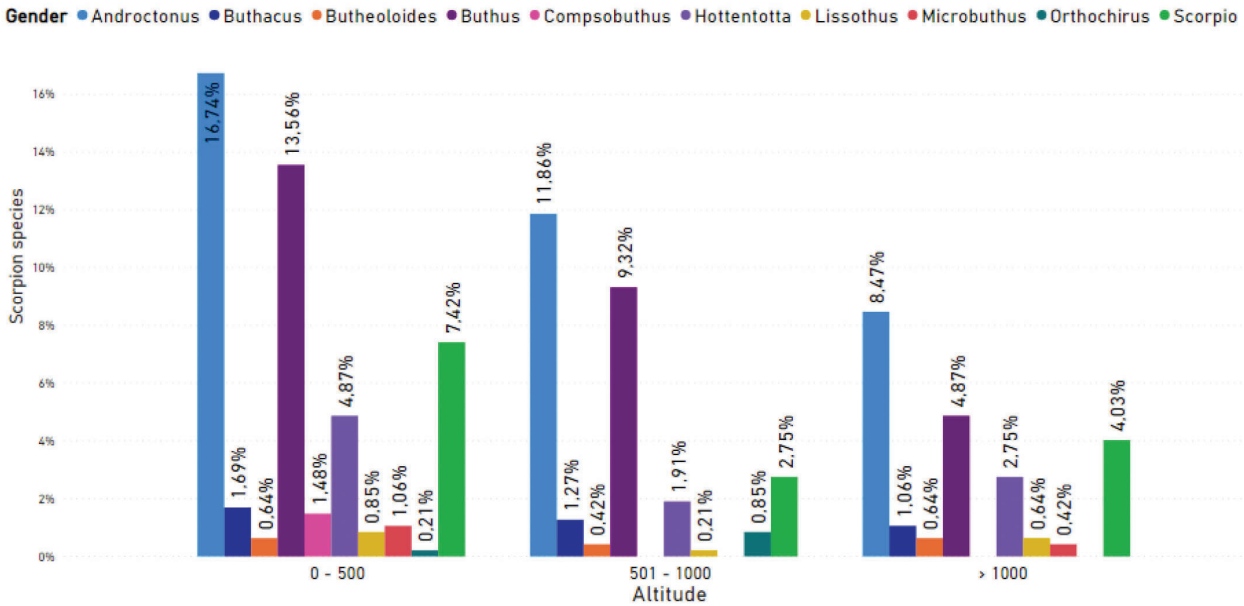
The results of the biodiversity distribution of scorpions in Morocco are shown on 32 zoogeobiographical maps. Figures 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 23, 22, 24, 25, 26, 27, 28, 29, 30, 31 and 32.

Discussion

The study gives a first view on biodiversity of scorpions in Morocco. This will lead to seeking more geographic parameters like density, toxicity and scorpion hot spots.

Contrary to what people think arid and Saharan regions do not contain a high biodiversity of scorpions but can be a high density. What is also astonishing is the presence of great biodiversity of the scorpion in the Casablanca-Settat region. It is a small, highly industrialized and urbanized region, which leads to asking several questions above.

A study to determine the density of scorpions in Morocco is essential and complimentary to clarify the vision of scorpions in Morocco.



Graph 6. Scorpion gender biodiversity according to Altitude

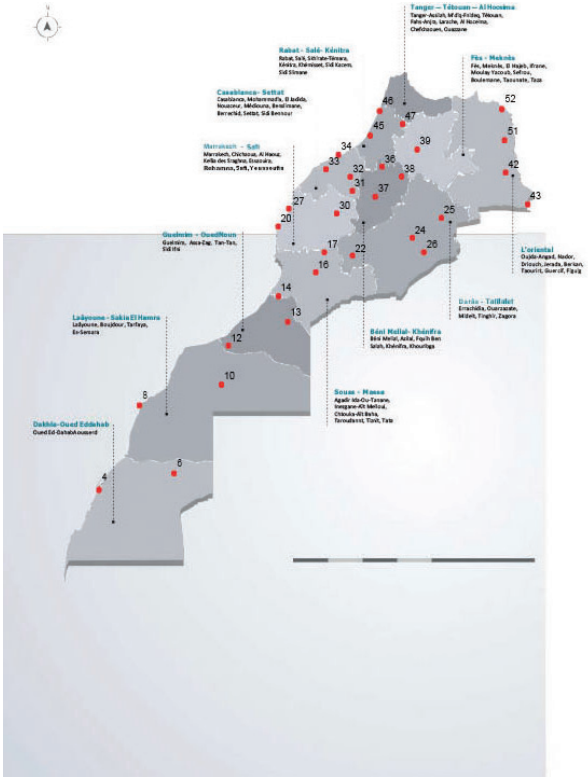


Fig. 1. *Androctonus amoreuxi*

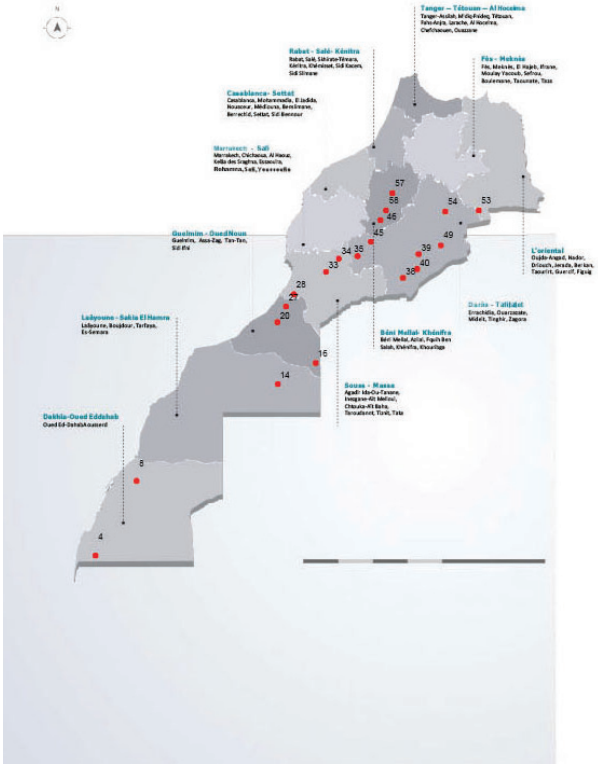


Fig. 3. *Androctonus bourdoni*

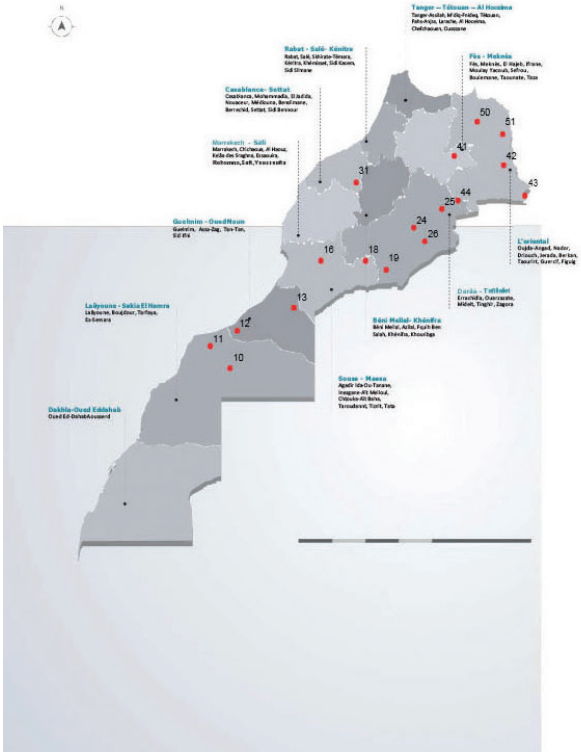


Fig. 2. *Androctonus australis*

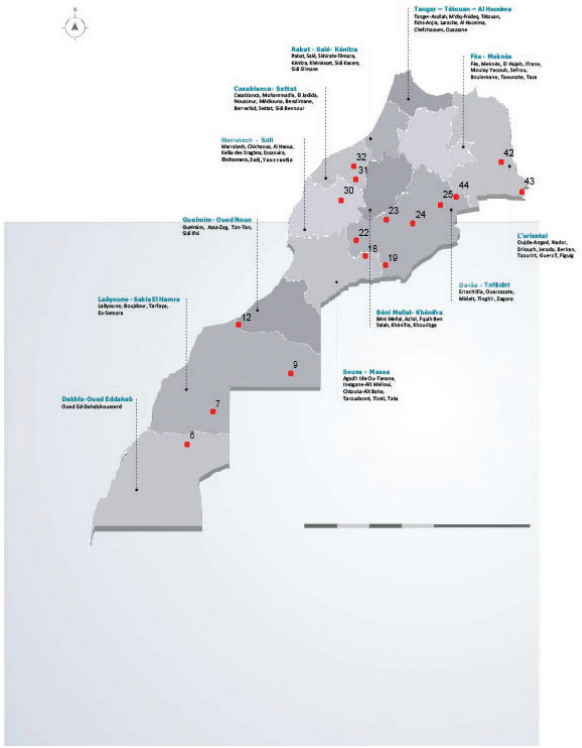


Fig. 4. *Androctonus gonneti*

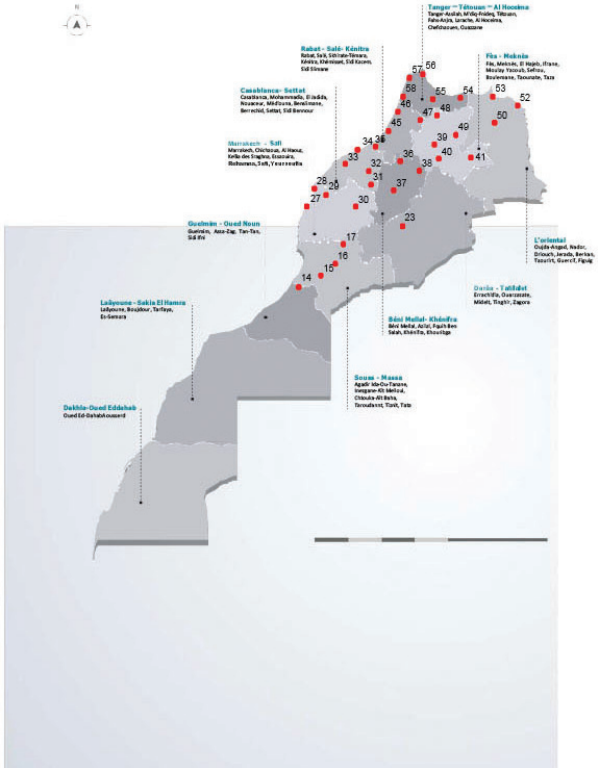


Fig. 5. *Androctonus liouvillei*

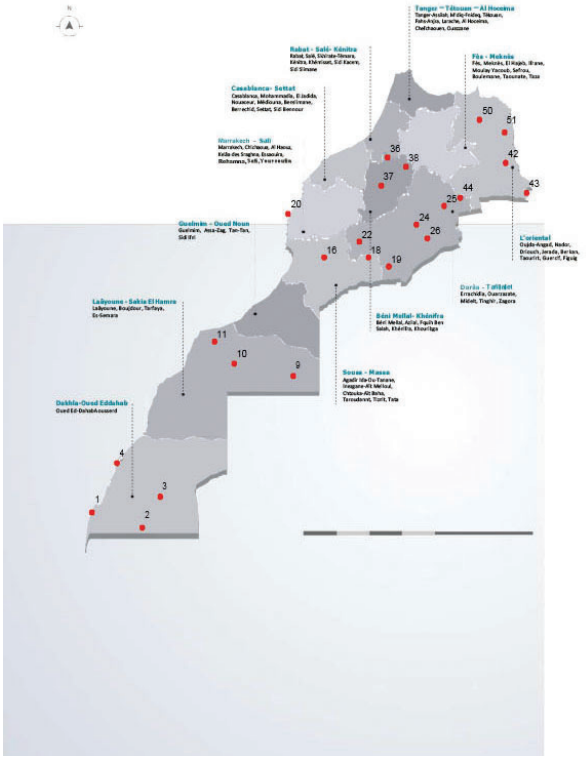


Fig. 7. *Androctonus sergenti*

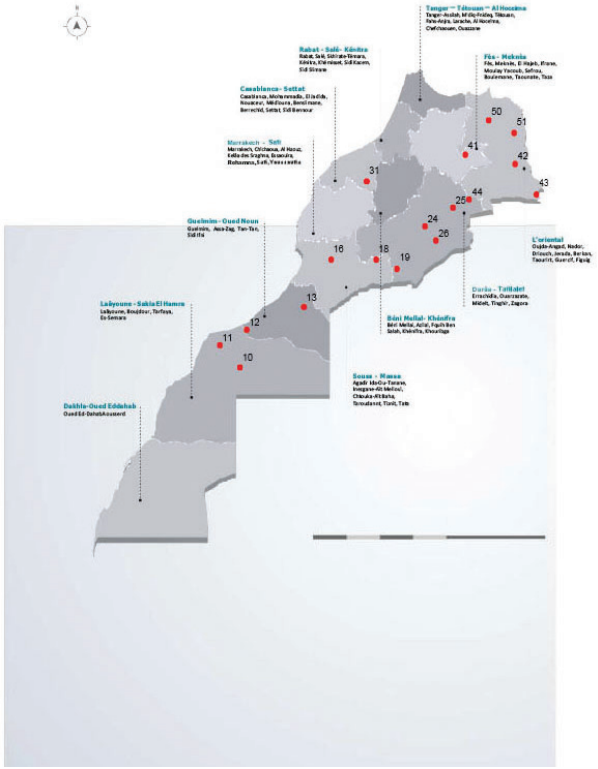


Fig. 6. *Androctonus mauritanicus*

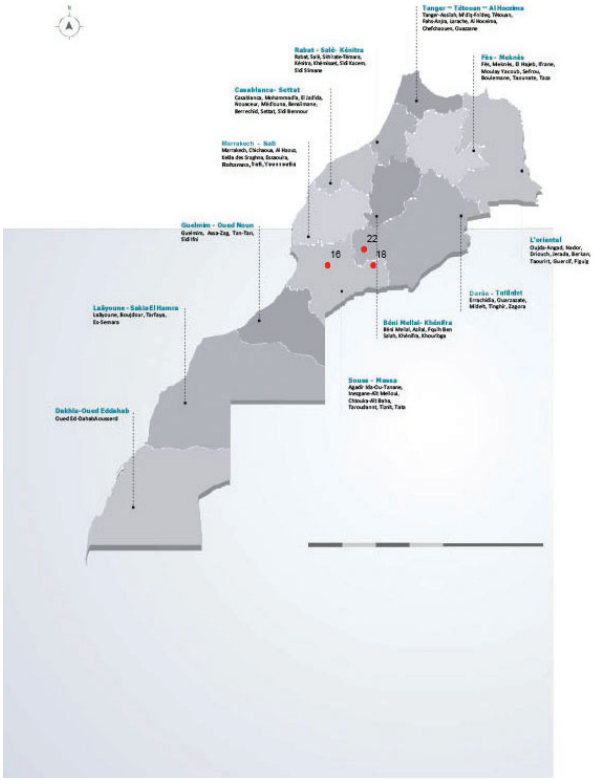


Fig. 8. *Buthacus arenicola*

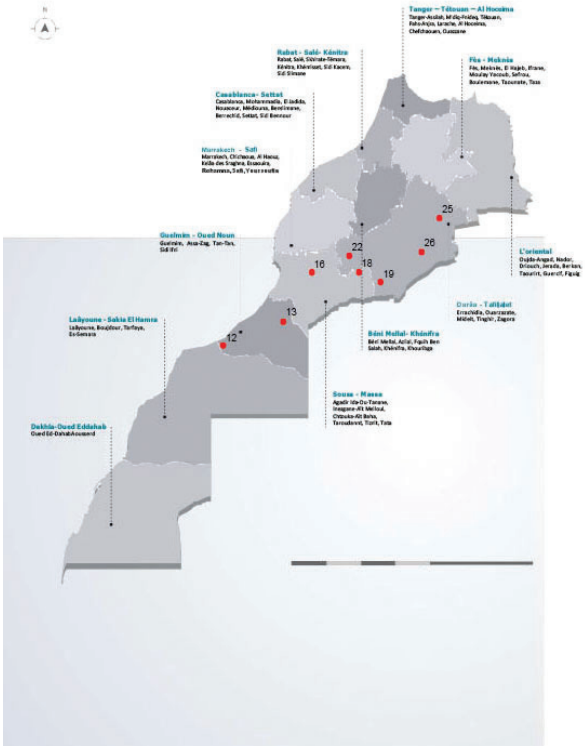


Fig. 9. *Buthacus leptochelys*

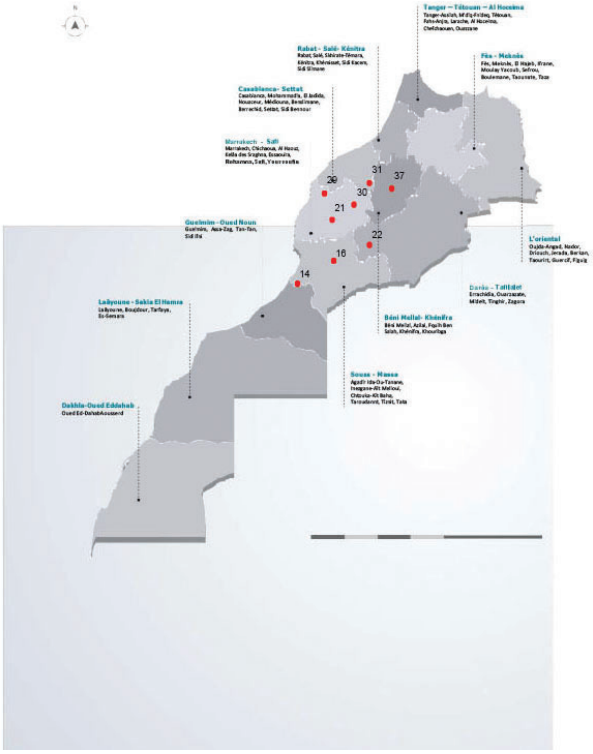


Fig. 11. *Butheloides maroccanus*

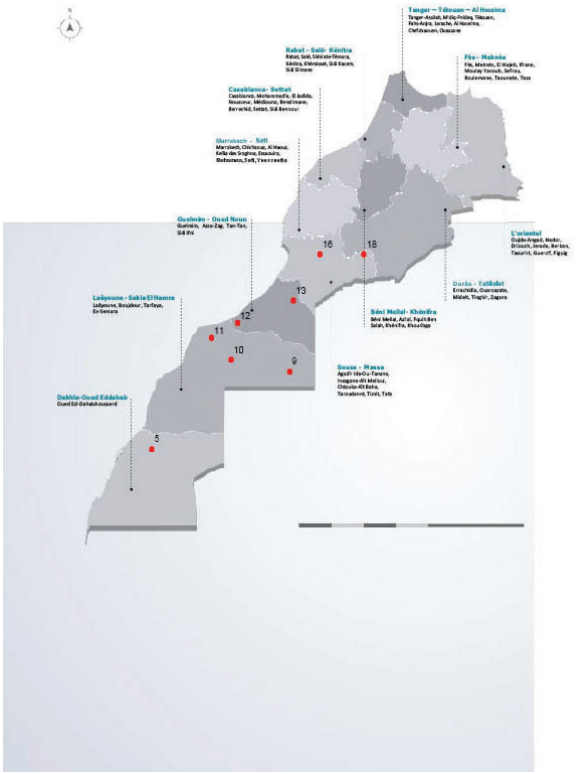


Fig. 10. *Buthacus stockmanni*

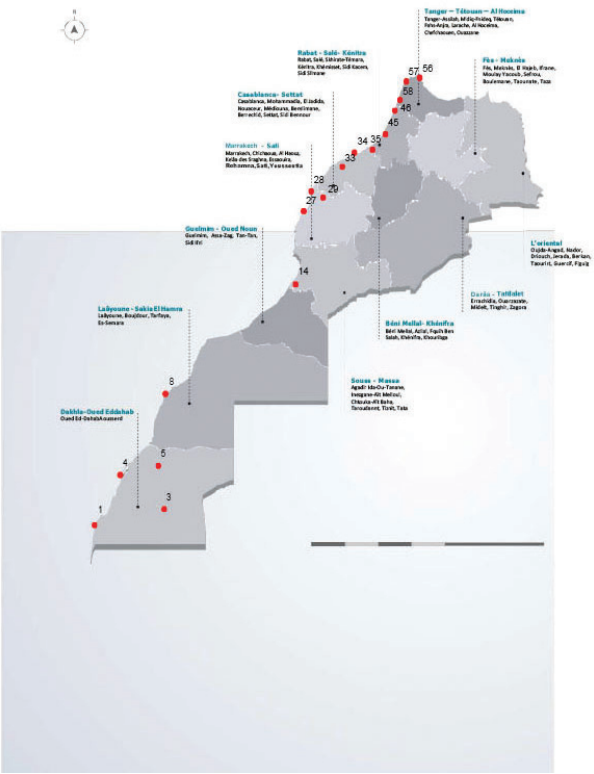


Fig. 12. *Buthus atlantis*

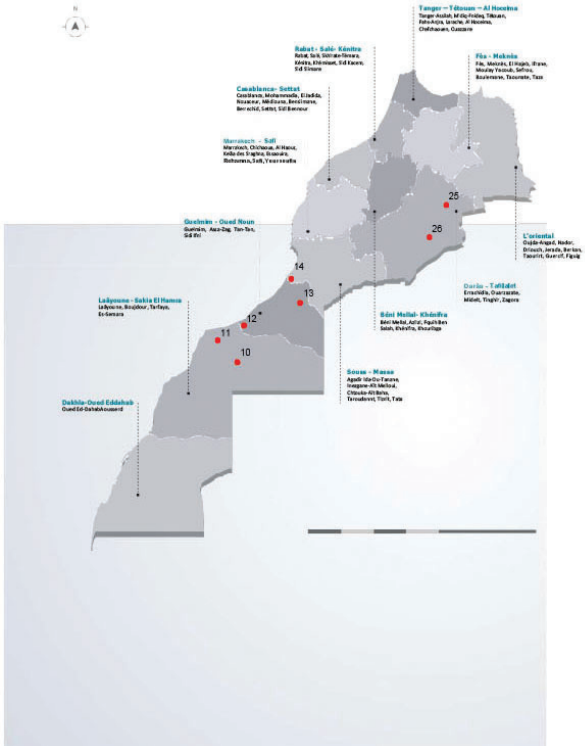


Fig. 13. *Buthus bonito*

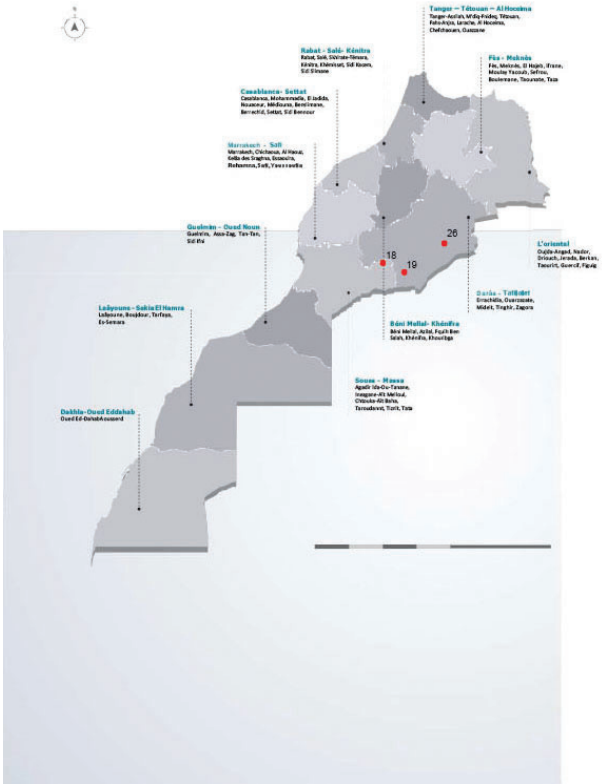


Fig. 14. *Buthus draa*

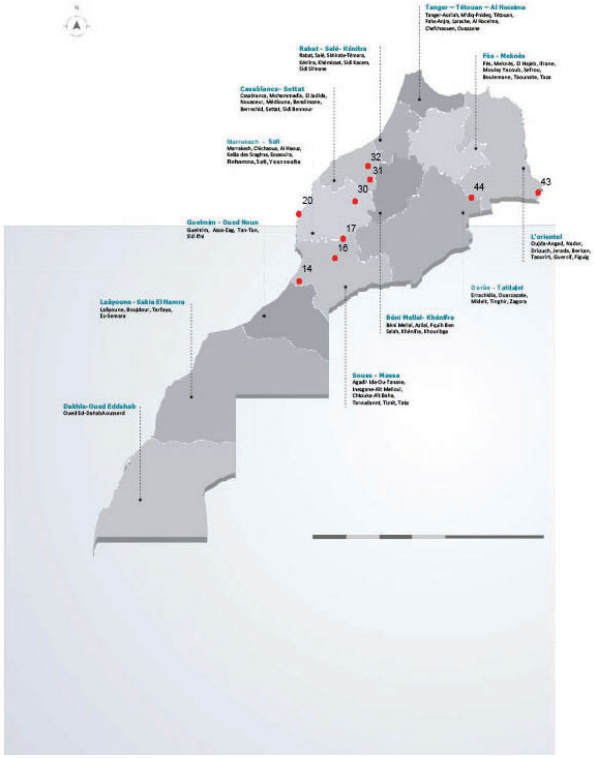


Fig. 15. *Buthus elmoutaouakili*

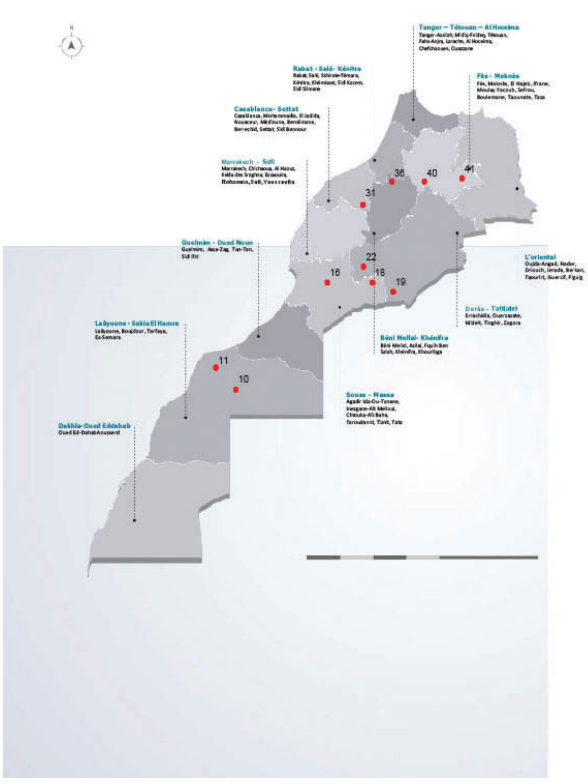


Fig. 16. *Buthus lienhardi*

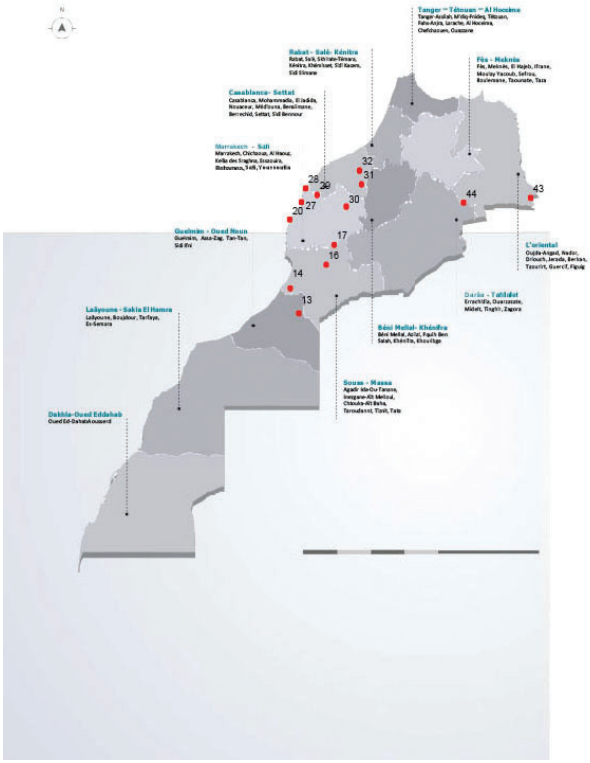


Fig. 17. *Buthus malhommei*

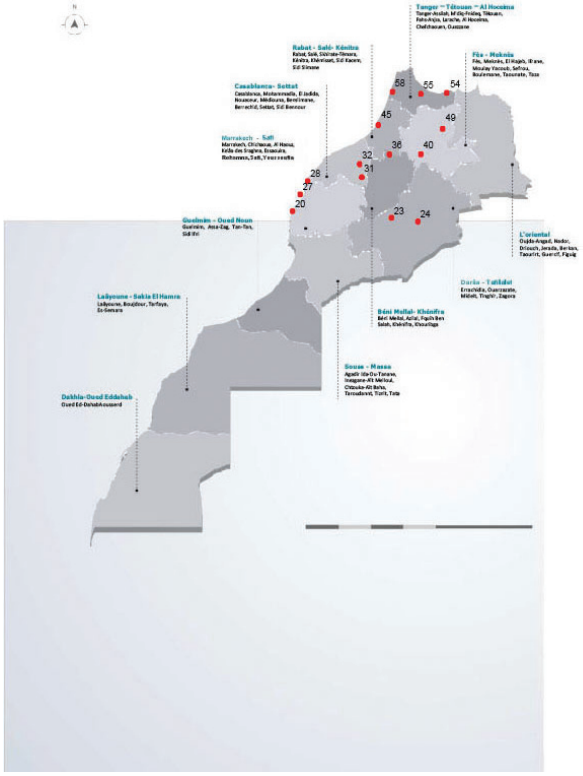


Fig. 19. *Buthus mariefrancae*

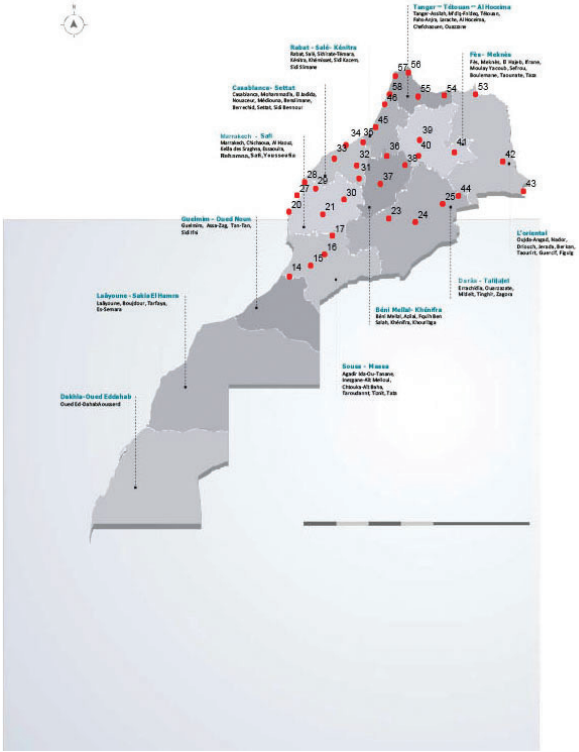


Fig. 18. *Buthus mardochei*

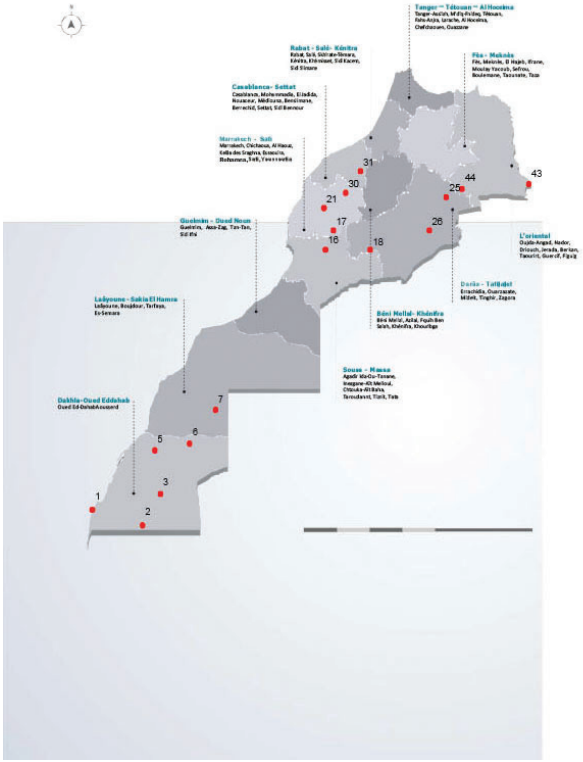


Fig. 20. *Buthus maroccanus*

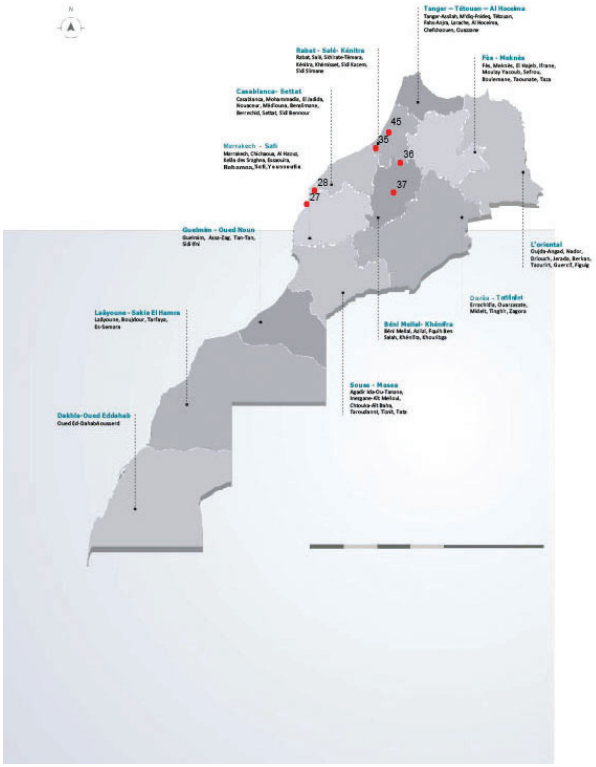


Fig. 21. *Buthus paris*

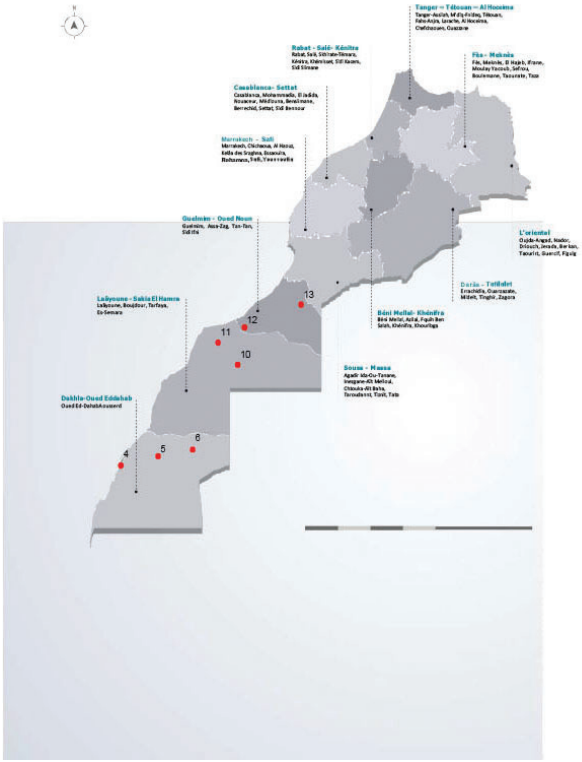


Fig. 22. *Compsobuthus turieli*

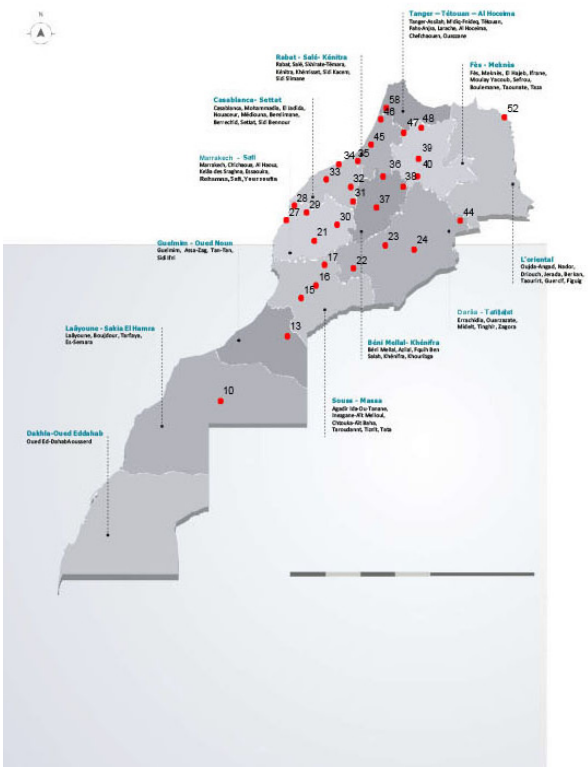


Fig. 23. *Hottentotta franzwerneri*

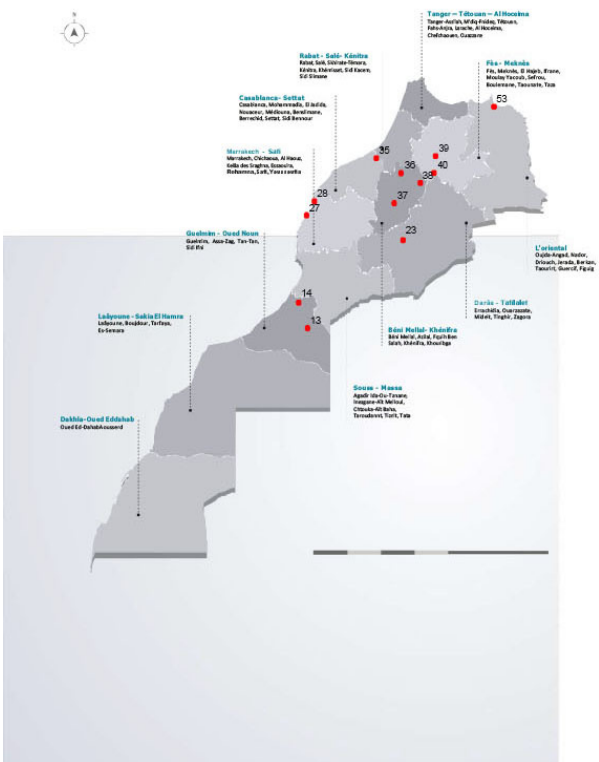


Fig. 24. *Hottentotta gentili*

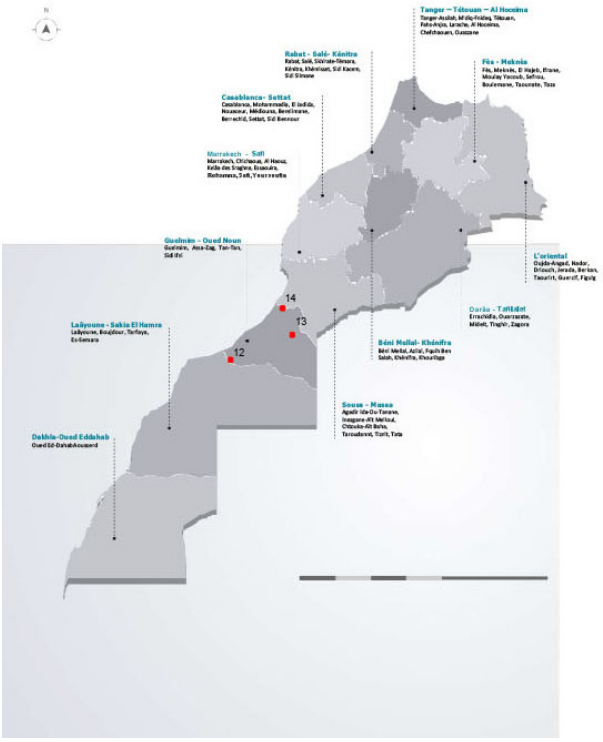


Fig. 25. *Hottentotta sousai*

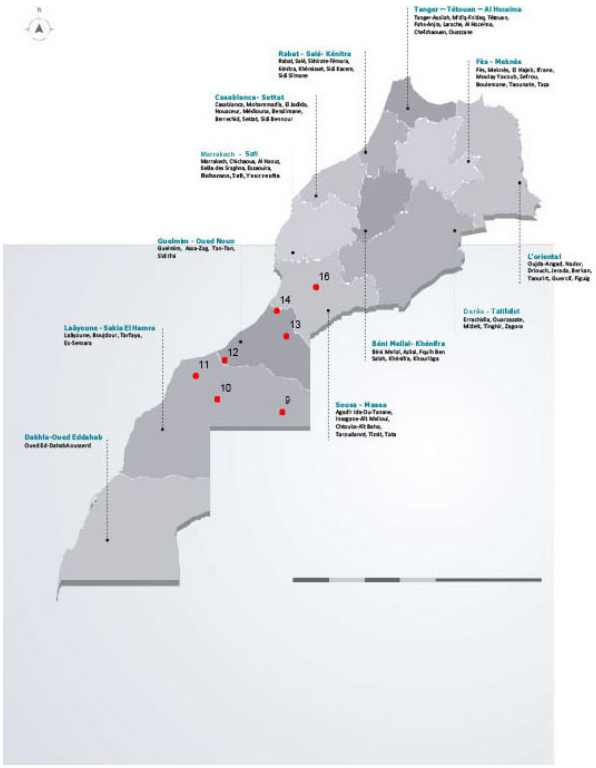


Fig. 27. *Microbuthus maroccanus*

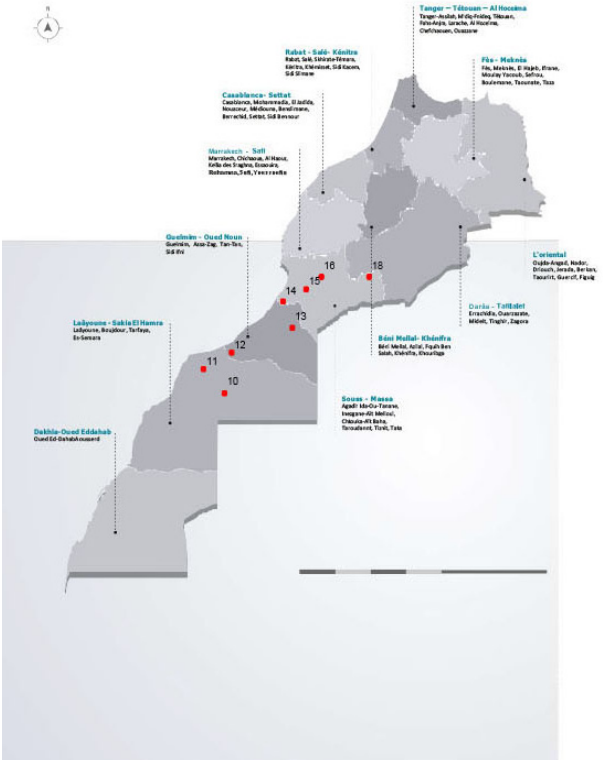


Fig. 26. *Lissothus occidentalis*

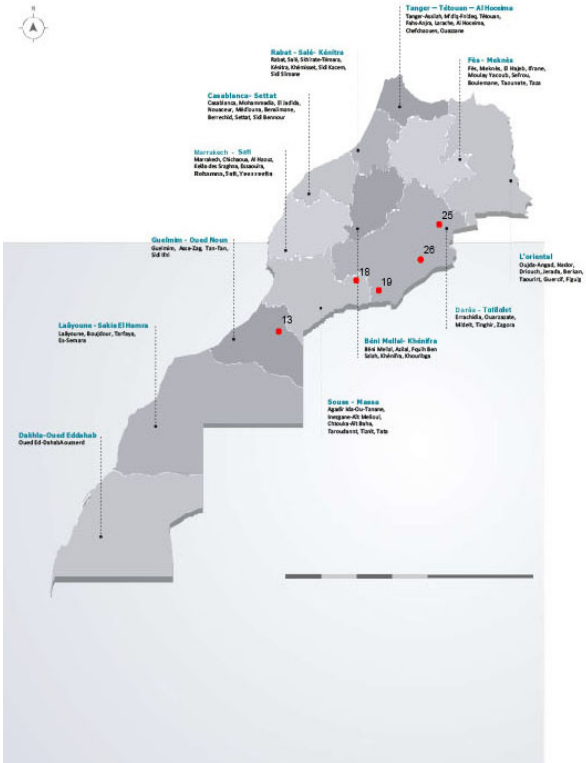


Fig. 28. *Orthochirus innesi*

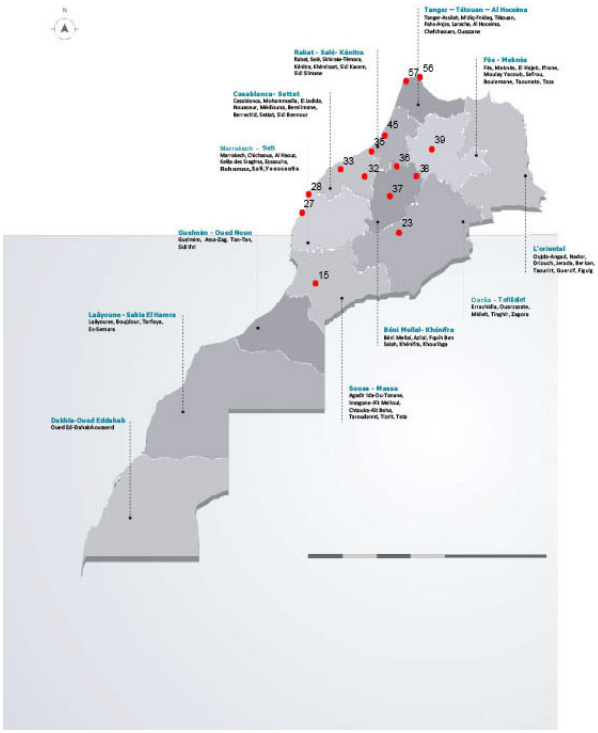


Fig. 29. *Scorpio fuliginosus*

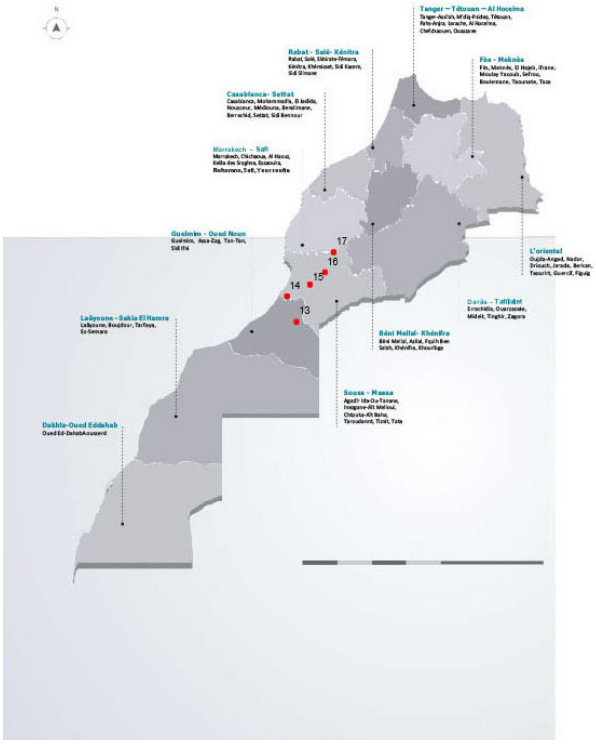


Fig. 31. *Scorpio mogadorensis*

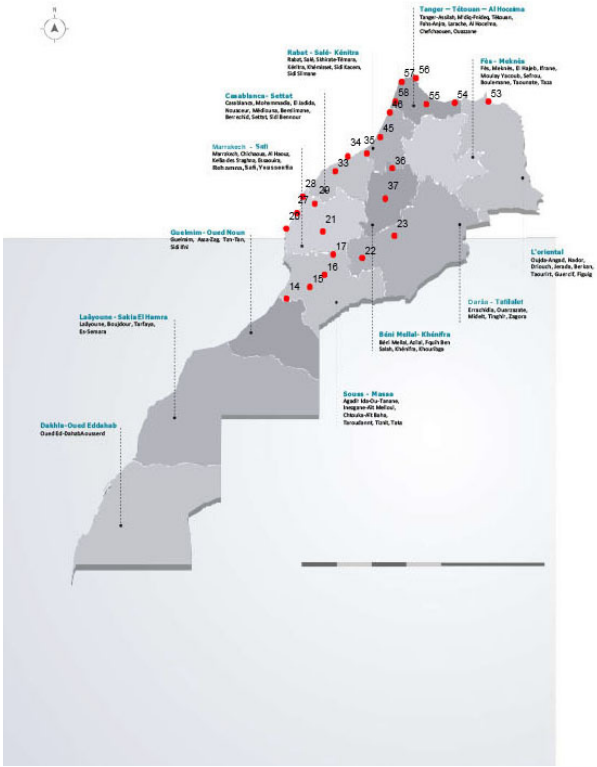


Fig. 30. *Scorpio maurus*

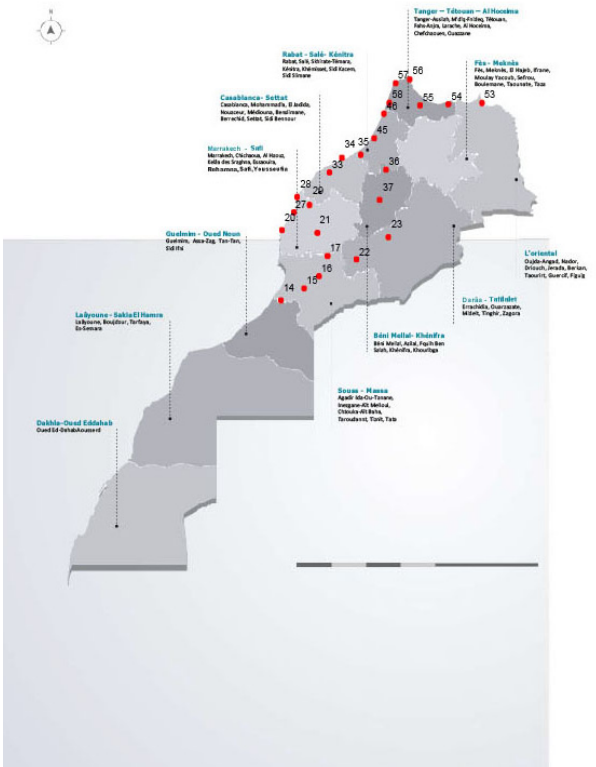


Fig. 32. *Scorpio palmatus*

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