
ZOOGEOGRAPHICAL ANALYSIS OF THE EGYPTIAN SCORPION FAUNA

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ABSTRACT

The geographical distribution and diversity of the scorpion fauna of Egypt was examined based on a large collection covering most of the country and in view of recent revisionary systematics. Six ecologically distinct zoogeographical regions are targeted in a collection scheme. The ecological and historical biogeography of the present-day distribution of the scorpion fauna of Egypt is discussed.

Key Word. Zoogeography, Scorpion Fauna, Buthidae, Euscorpiidae, Hemiscorpiidae, Scorpionidae, Egypt

INTRODUCTION

Scorpions comprise a highly successful and diverse order of Arachnida. Except Antarctica, scorpions distributed over all continents (Lamoral, 1980; Sissom, 1990). It inhabits a great range of the world of tropical and temperate regions including; forests, savannas and deserts (Anderson, 1983).

The scorpion fauna of Egypt is represented by four families; Buthidae, Euscorpiidae, Hemiscorpiidae and Scorpionidae. During the past century, considerable information about scorpion fauna of Egypt and the region, have been compiled, reviewed and synthesized by several authors (e.g. Simon, 1910; Gough and Stanley, 1927; Pallary, 1937; Vachon, 1952; 1966; Levy and Amitai, 1980; Vachon and Kinzelbach, 1987). Numerous publications have contributed significantly to our growing knowledge of the composition, ecology and biogeography of scorpions of Egypt at large (Kinzelbach, 1985; Moustafa, 1988; EL-Hennawy, 1992; Lourenço *et al.*, 2009a, b; Teruel *et al.*, 2013). These authors refer to a total of 35 scorpion species from Egypt. All of these species were listed in a compiled lists El-Hennawy (1992, 2014). Some of these species records are unclear and dubious (Kovarik, 2007; Kaltsas *et al.*, 2008) and should be further reviewed and verified. Moreover, the taxonomy and diversity of the scorpion fauna of Egypt was examined based on a large

collection from most parts of the country and in view of recent revisionary systematics. The validity of listed records was assessed in light of new taxonomic findings and geographic distribution data and present a new list provided with an identification key to the scorpion fauna of Egypt consisting of 31 species and four dubious species (Badry *et al.*, 2017). In addition, the precise patterns of geographical and ecological distribution of most scorpion species in Egypt are yet to be determined.

Egypt occupies one of the most arid areas on the globe. It's an important part of North Africa, which are home to a unique fauna and flora that has been shaped by the combination of several factors including the harsh climatic conditions of the Sahara the episodic appearance of humid cycles, and by the complex geological evolution of this area. The aim of this paper is to explain current geographical distribution of different scorpion species from Egypt.

MATERIALS AND METHODS

Study area

The study covers the entire country of Egypt (Figure, 1 and Table, 1), which is traditionally divided into a number of ecogeographical regions, each encompassing a number of basic habitat types (Kassas, 1993;

Saleh, 1993). These eco-geographical regions can be summarized as following;

The Mediterranean Coastal Desert: This narrow coastal strip of 30 to 50 kms extends along the Egyptian coast of the Mediterranean. It receives more rainfall than any other area in Egypt. With the exception of the extreme eastern part, which is considered semi-arid, the rest of the coastal belt is climatically arid. The hyper-arid barren desert to the south forms a major ecological barrier separating this belt from the patchy inland habitats of the Western Desert to the south (Saleh, 1993). The Mediterranean coastal belt is interrupted by the Nile Delta which divides it into the Western Mediterranean Coastal Desert (WMCD) to the west, and the Eastern or Sinai Mediterranean Coastal Desert (SMCD) to the east. These two sectors, differ geomorphologically, climatologically and ecologically from each other (Saleh, 1997) and are, therefore, treated in this study as two separate eco-geographical regions.

The Western Inland Desert (WID): South of the Mediterranean coastal desert, the Western Desert is almost rainless. The flat topography of that desert allows very little, if any, significant collection of the rare local rain to support even the most rudimentary life. In the topographic depressions scattered throughout that desert, however, ground water may reach the surface creating oases and other isolated patches of life in this otherwise barren desert. These patchy habitats are surrounded by vast tracks of barren desert which represent a formidable ecological barrier to animals, particularly those with limited dispersal abilities. Patchy inland habitats of the Western Desert include the inhabited oasis groups of Siwa, Bahariya, Farafra, Dakhla, and Kharga, as well as numerous uninhabited oases, acacia groves and vegetation patches scattered throughout that desert, the largest of which is the Qattara Depression and its satellite oases. Within most of the large oasis depression life is distributed in smaller secondary patches where

water is available forming individual oases that are often separated from each other by barren desert.

The Nile Valley and Delta (NVD): The River Nile, which cuts its course across the entire length of the country, carries an abundance of water from the remote African highlands into this extremely arid part of the Sahara, creating in its narrow valley and delta the largest riverine oasis in the world. The river flows mostly close to the north-south aligned hills of sandstone and limestone of the Eastern Desert. South of the large and intensively cultivated Nile Delta, the present-day flood plain of the Nile becomes very narrow, particularly on the eastern side, where the river washes the feet of the sedimentary hills of the Eastern Desert in some places. Adjoining the river's western flood plain just south of the latitude of Cairo is the Faiyum Depression. The depression receives its water from the Nile via the Bahr Yusuf canal, which is possibly a natural branch of the Nile. South of Aswan, the river cuts a deep, gorge-like course through the Nubian Plateau. This fast running sector of the river is interrupted by a series of rapids forming what is known as the river Cataracts. From the First Cataract just south of Aswan, the river virtually lacks any flood plain, except for few patches scattered along the river course. Following the damming of the river near Aswan, this sector of the river has been inundated. The resulting Lake Nasser forms one of the major topographic features of the entire river basin.

The Eastern Inland Desert (EID): Unlike the Western Desert, the Eastern Desert exhibits a very diverse and complex topography. A backbone of igneous mountains running along the longitudinal axis of this desert, but closer to the Red Sea coast is the predominant topographic feature. This mountain chain is skirted to the north and west by sedimentary plateaus of limestone and sandstone. Both the igneous mountains and the sedimentary plateaus are dissected by networks of drainage

channels, which collect water from larger watersheds into the much smaller areas of the wadis or their deltas to eventually discharge into the Red Sea or the Nile River. Wadi channels and deltas thus receive runoff water many times higher than the average local precipitation, which ranges from 25 to 50 mm annually. The drainage networks also serve as corridors for movement of fauna across this otherwise inhospitable desert. The dramatically different riverine habitat of the Nile Valley and Delta forms a major ecological barrier preventing Eastern Desert fauna from venturing west. To the northeast the Isthmus of Suez, with its wetland presents another ecological barrier between the Eastern Desert and Sinai (Basuony and Saleh, 2005).

The Sinai Peninsula: The Sinai Peninsula is a triangular plateau with its head in the south at Ras Mohammad and its base along the Mediterranean Sea. The peninsula is geologically and geomorphologically an extension of the Eastern Desert, regardless of the Gulf of Suez that separates the two regions. The core of the peninsula; situated near its southern end; consists of an intricate complex of high and very rugged igneous and metamorphic mountains. These mountains are dissected by a large number of wadis flowing either to the Gulf of Aqaba or the plain of Sahel El Qaa and the Gulf of Suez. Most of these wadis are relatively rich in plant and animal life. The Mediterranean littoral desert of Sinai called Sinai Mediterranean Coastal Desert (SMCD) consists of wide, sand-covered plains gradually sloping northward. Eolian sand dunes with elevations of 80 to 100 m are common throughout the region. Wadi El Arish, a very large northward-flowing wadi, with numerous tributaries draining extensive areas of the Central Sinai highlands is one of the main geomorphologic features of the region. South of the Mediterranean coastal belt of Sinai, a number of distinct hill groups, which include Gabal El-Maghara, Gabal El-Halal, Gabal Yelleq and others form the so-called the region

of domes (Abu Al-Izz, 1971), located relatively close to the Mediterranean. These hills receive higher precipitation and support an interesting variety of relict fauna and flora. South of this region, the central Sinai plateau begins called Sinai Inland Desert (SID). This region encompasses the rugged sedimentary country of El Tih and Al-Ugma Plateaus, which are located on the northern flanks of the great igneous core. These plateaus form two ridges, which have the form of straight walls with no gaps (Shata, 1959). Numerous wadis drain the central Sinai plateaus into the lower areas to the north and often support rich and diverse flora (Saleh, 1993).

Each of the above eco-geographical regions is surveyed at a number of collection localities that represent its different habitat types.

Material Examined

The materials examined during this study consist of a total of 962 scorpion specimens currently deposited at Al Azhar University Zoological Collection (AUZC), Department of Zoology, Al Azhar University, Cairo, Egypt. The majority of these specimens were collected during the course of this study. These specimens were collected from 46 collection localities representing six major eco-geographical regions of Egypt (Figure, 1 and Table, 1). Scorpions were collected by actively searching their potential hiding places, mostly under rocks during daytime (Williams, 1968) and at night using ultraviolet light (Stahnke, 1972). Collected specimens were preserved for future morphological and taxonomical studies, as described by Williams (1968).

Morphological examination and species identification

The specimens were examined by a stereoscopic binocular microscope, and photographed with a digital camera. The collected scorpions were identified to the species level based on keys and morphological descriptions of Vachon (1966), El-Hennawy

(1987), Lourenço and Simon (2012) and Rossi (2013).

RESULTS

The compiled list (Table, 2) shows that scorpion species richness varies considerably among different eco-geographical regions in Egypt (Figure, 2). Among the 31 species belong 15 genera of known collection localities in Egypt (Table 2), Inland (48% of all species) occur in the Nile Valley and Delta (NDV) and Eastern Desert (EID). Five species includes; *Compsobuthus kabateki*, *Hottentotta minax*, *Isometrus maculatus*, *Parabuthus hunteri* and *Hemiscorpius egyptiensis* are restricted to Nile Valley and Delta, while only four of these species (*Buthus intumescens*, *Hottentotta scaber*, *Microbuthus flavorufus* and *Parabuthus leiosoma*) are restricted in their distribution to Eastern Inland Desert (EID) ecoregion. Also, twelve species (38% of the fauna) are recorded from the Western Mediterranean Coastal Desert (WMCD), four of which (*Androctonus tenuissimus*, *Buthus adrianae*, *Buthus orientalis* and *Euscorpius sicanus*) are restricted to that ecoregion. Sinai Inland Desert (SID), Sinai Mediterranean Coastal Desert (SMCD) and Western Inland Desert (WID) account for 9, 8, and 8 (29, 25.8, 25.8%) of the recorded species, respectively. Three of the Sinai Inland Desert species (*Buthus israelis*, *Compsobuthus longipalpis*, and *Orthochirus scrobiculosus*), and one each of the Sinai Mediterranean Coastal Desert (SMCD) and Western Inland Desert (WID) (*Egyptobuthus vaissadei* and *Buthus egyptiensis*, respectively) are restricted to their respective ecoregions.

Different species appear to vary considerably in their distribution among the six eco-geographical regions covered in this study (Figure, 3). Of the 31 species with known collection localities, two species (*Androctonus amoreuxi* and *Leiurus quinquestriatus*) appear to have high ecological tolerance and have been recorded from all six eco-geographical regions. On the other hand, 18 species appear to be restricted in their distribution to a specific

ecoregion, outside of which it has never been recorded. The remaining 13 species have been recorded from 2 to 5 ecoregions.

DISCUSSION

Saharan fauna characteristically consists of primarily Palearctic fauna, with some Afrotropical elements (Dobson and Wright, 2000) reflecting the geological, biogeographic and ecologic history of the region. The scorpion fauna of Egypt, similarly consists of both Palearctic and Afrotropical elements. Of the 15 Egyptian scorpion genera, 14 have Palearctic affinity and only one genus (*Parabuthus*) is Afrotropical. The two Afrotropical species *Parabuthus hunteri* and *P. leiosoma* have been reported from the Nile Valley and the arid to semi-arid, extreme southeastern region of Egypt which is dominated by Afrotropical fauna (Saleh, 1993).

One of the most distinct characters of the scorpion fauna of Egypt is its highly disjunct distribution. This is obviously a consequence of the patchy distribution of habitats, which is, in turn dictated by the rare availability of water in this mostly hyper-arid region of the Sahara. Fragmented animal populations, in their habitat patches, are often separated from one another by large tracts of barren desert. This waterless, lifeless desert creates a formidable barrier for the dispersion of scorpion, and even larger animal species with greater mobilization abilities. The isolation of scorpion populations into desert habitat islands may have taken place during the Pleistocene's successive episodes of arid climate, but has finally persisted since the onset of the present arid conditions in the Sahara around the middle of the Holocene (Said, 1990; Roberts, 1998; Béatrix, 2001). This vicariance explanation for the present-day distribution of most terrestrial animal groups in Egypt is more plausible, as dispersal is unlikely to be the mechanism because of the nature of the ecological barriers separating different populations (Nelson and Platnick, 1980; Morrone and Crisci, 1995).

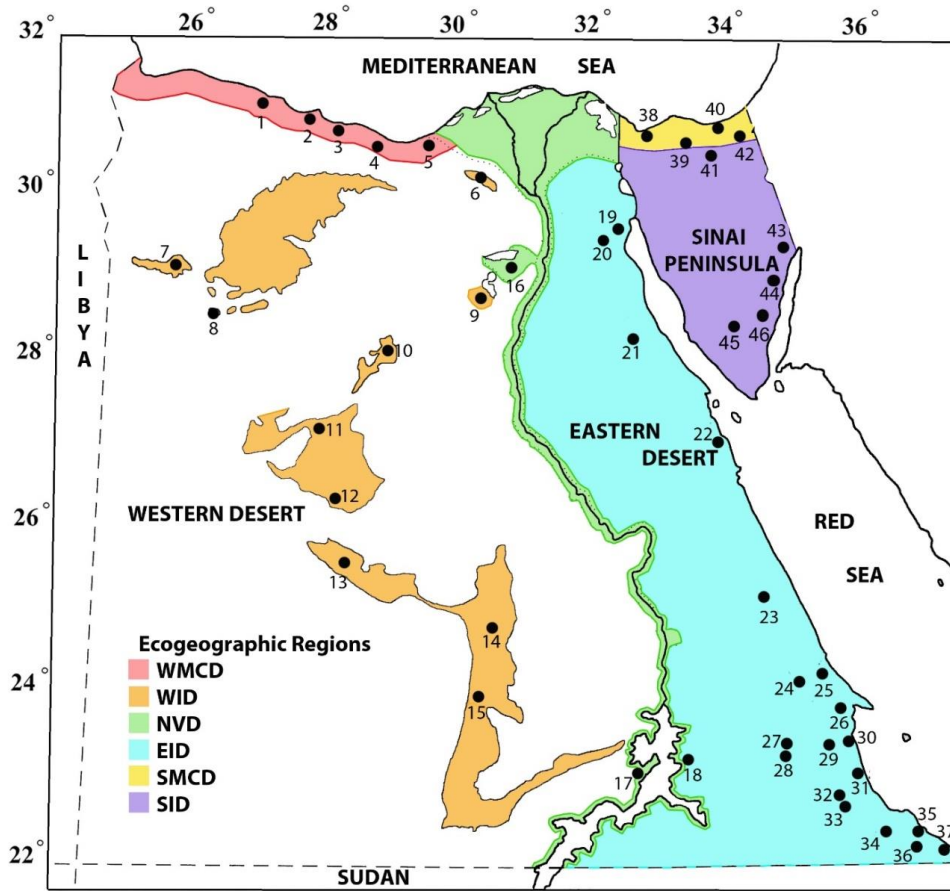


Figure 1. Location map of eco-geographical regions and collection localities covered in this study.

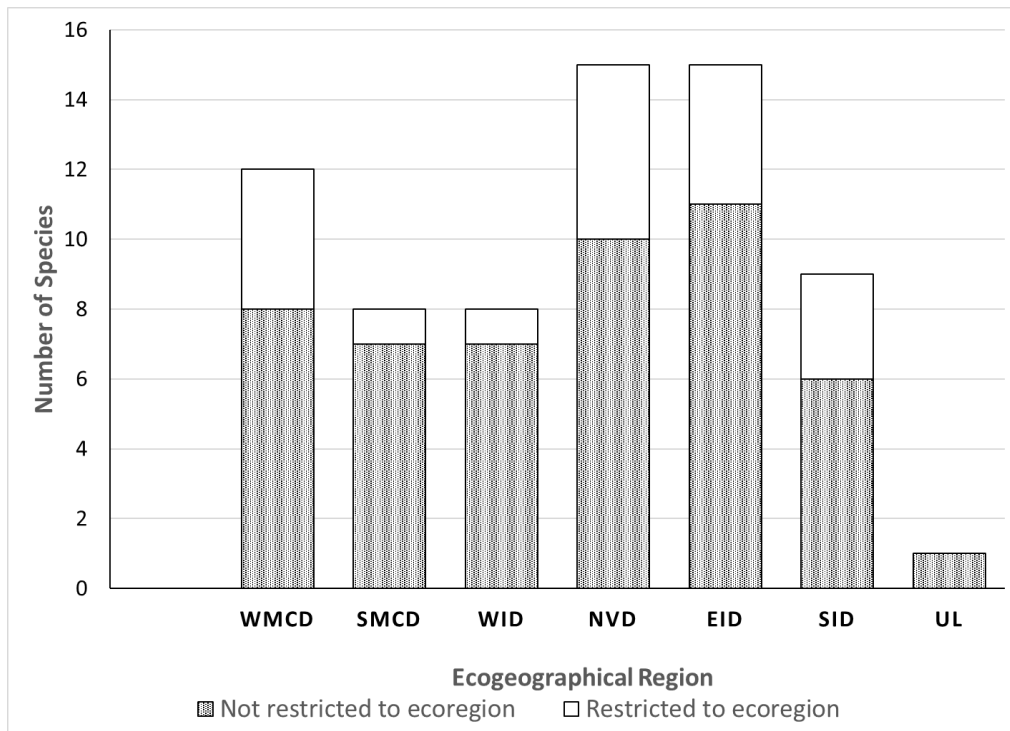


Figure 2. Number of species recorded from different eco-geographical regions of Egypt; WMCD (Western Mediterranean Coastal Desert), SMCD: (Sinai Mediterranean Coastal desert), WID (Western Inland Desert), NVD (Nile Valley and Delta), EID (Eastern Inland Desert), SID (Sinai Inland Desert); and UL (unknown localities).

Table 1. Locations of the investigated sites during the survey. WMCD = Western Mediterranean Coastal Desert; SMCD = Sinai Mediterranean Coastal Desert; WID = Western Inland Desert; NVD = Nile Valley and Delta; EID = Eastern Inland Desert; SID = Sinai Inland Desert.

N	Sites	Eco-geographical regions	Latitudes	Longitudes
1	Marsa Matruh	WMCD	31.1918	27.6211
2	Sidi Heneish		31.0701	27.7905
3	El-Dabaa		30.9626	28.4739
4	El-Hammam / El- Omaiyed protectorate		30.8585	29.4026
5	Borg El Arab		30.6887	28.9466
6	Wadi El-Natron	WID	30.3318	30.1212
7	Siwa Oasis		29.1513	25.7934
8	Bahrain		28.6886	26.4508
9	Wadi El Rayan		29.2147	30.4223
10	Bahariya Oasis		28.2759	28.8006
11	Farafra Oasis		27.0776	27.9754
12	Abu Mingar		26.5060	27.6451
13	Dakhla Oasis		25.4945	28.9789
14	Kharga Oasis		25.7271	30.5549
15	Baris		24.6744	30.6079
16	Faiyum	NVD	29.2799	30.5763
17	West of Lake Nasser		23.2890	32.7768
18	East of Lake Nasser		23.1813	32.9883
19	Ghobet El Bous	EID	29.6180	32.0966
20	Wadi Ghoieiba		29.9080	32.3308
21	Wadi Al Tarfa		28.2618	32.1626
22	Hurgada		27.1416	33.6957
23	Wadi Nekheil		25.1515	34.3910
24	Wadi Halos		24.3936	35.0766
25	Wadi El Ranga		24.3514	35.1930
26	Wadi Khodaa		23.8245	35.3134
27	Bir Abraç		23.4188	34.7989
28	Abu Saafa		23.2984	34.7842
29	Wadi El Rahaba		23.4284	35.2395
30	Marsa Hemira		23.4743	35.4813
31	Shalateen		23.1348	35.5909
32	Wadi Sha`b		22.3155	35.9493
33	El Garf		22.6664	35.3502
34	Wadi El-De`ib		22.2065	36.3777
35	Abu Ramad		22.3936	36.4011
36	Wadi Aydeib		22.2065	36.3777
37	Halayeb	22.1694	36.6665	
38	Bir El-Abd	SMCD	31.0142	32.7486
39	Gabal Yelleq		30.3688	33.5161
40	El Arish		31.0729	33.8326
41	Gabal El-Maghara		30.6776	33.4845
42	El Shikh Zuweid		30.8828	34.0629
43	El Naqab Desert	SID	29.5339	34.7031
44	Wadi El Shafalah		29.3246	34.5997
45	Wadi Arada		28.8620	34.1604
46	Ain Khadra		28.8959	34.4223

Table 2. Scorpion families and species recorded from different eco-geographical regions of Egypt based on published data and the results of the present survey. WMCD = Western Mediterranean Coastal Desert; SMCD = Sinai Mediterranean Coastal Desert; WID = Western Inland Desert; NVD = Nile Valley and Delta; EID = Eastern Inland Desert; SID = Sinai Inland Desert; UL = Unknown Localities/Dubious record.

Family and species	Eco-geographical Region							Authority*
	WMCD	SMCD	WID	NVD	EID	SID	UL	
DEFINITIVE SPECIES								
Buthidae								
<i>Androctonus amoreuxi</i>	+	+	+	+	+	+	-	1, 2, 3, 4, 5, 6, 7, 8, 9
<i>Androctonus australis</i>	+	+	+	+	+	-	-	1, 3, 4, 5, 8, 10, 11, 12, 13
<i>Androctonus bicolor</i>	+	+	-	+	+	-	-	1, 2, 3, 4, 5, 8, 12, 13, 14, 15
<i>Androctonus crussicauda</i>	-	+	-	-	-	+	-	1, 13, 14, 15
<i>Androctonus tenuissimus</i>	+	-	-	-	-	-	-	1, 16
<i>Buthacus arenicola</i>	+	-	-	-	+	-	+	17
<i>Buthacus leptocheilus</i>	+	+	+	+	+	-	-	1, 3, 5, 8, 10, 13, 14, 18, 19
<i>Buthus adrianae</i>	+	-	-	-	-	-	-	1, 20
<i>Buthus egyptiensis</i>	-	-	+	-	-	-	-	21
<i>Buthus intumescens</i>	-	-	-	-	+	-	-	1
<i>Buthus israelis</i>	-	-	-	-	-	+	-	22, 23
<i>Buthus orientalis</i>	+	-	-	-	-	-	-	1, 24
<i>Compsobuthus egyptiensis</i>	-	-	+	+	-	-	-	1, 25
<i>Compsobuthus kabateki</i>	-	-	-	+	-	-	-	26
<i>Compsobuthus werneri</i>	-	-	-	+	+	+	-	1, 14, 27, 28
<i>Compsobuthus longipalpis</i>	-	-	-	-	-	+	-	29
<i>Egyptobuthus vaissadei</i>	-	+	-	-	-	-	-	30
<i>Hottentotta minax</i>	-	-	-	+	-	-	-	11, 31
<i>Hottentotta scaber</i>	-	-	-	-	+	-	-	34
<i>Isometrus maculatus</i>	-	-	-	+	-	-	-	35
<i>Leiurus quinquestriatus</i>	+	+	+	+	+	+	-	1, 2, 3, 4, 5, 6, 8, 11, 12, 13, 15, 32, 33
<i>Microbuthus flavorufus</i>	-	-	-	-	+	-	-	34
<i>Orthochirus aristidis</i>	-	-	-	+	+	-	-	1, 4, 6, 26, 36, 37
<i>Orthochirus innesi</i>	+	-	+	-	+	-	-	1, 5, 8, 13, 37, 38, 39
<i>Orthochirus scrobiculosus</i>	-	-	-	-	-	+	-	1, 40
<i>Parabuthus hunter</i>	-	-	-	+	-	-	-	5
<i>Parabuthus leiosoma</i>	-	-	-	-	+	-	-	1, 41, 42
Euscorpidae								
<i>Euscorpius sicanus</i>	+	-	-	-	-	-	-	35, 43
Hemiscorpiidae								
<i>Hemiscorpius egyptiensis</i>	-	-	-	+	-	-	-	44
Scorpionidae								
<i>Nebo hierichonticus</i>	-	+	-	+	+	+	-	1, 4, 5, 8, 13, 14, 15, 45
<i>Scorpio maurus</i>	+	-	+	+	+	+	-	1, 4, 5, 8, 13, 14, 15
Total	12	8	8	15	15	9	1	
DUBIOUS SPECIES								
Buthidae								
<i>Buthus occitanus</i>	+	-	-	+	+	+	-	3, 5, 12, 32, 35
<i>Compsobuthus acutecarinatus</i>	+	-	+	+	-	+	-	5, 6, 12, 18, 35
<i>Hottentotta hottentotta</i>	-	-	-	-	-	-	+	31
<i>Hottentotta trilineatus</i>	-	-	-	-	-	-	+	33

* 1 this study; 2 Audouin, 1825; 3 Pocock, 1895; 4 Simon, 1910; 5 Gough and Stanley, 1927; 6 Birula, 1928; 7 Roewer, 1943; 8 Vachon, 1966; 9 El-Hennawy, 1991; 10 Hemprich and Ehrenberg, 1829; 11 Koch, 1875; 12 Tullgren, 1909; 13 Kinzelbach, 1985; 14 Levy and Amitai, 1980; 15 Moustafa, 1988; 16 Teruel *et al.*, 2013; 17 Lourenco, 2006; 18 Whittick, 1941; 19 El-Hennawy, 1991; 19; 20 Rossi, 2013; 21 Lourenço and Cloudsley-Thompson, 2012; 22 Lourenço *et al.*, 2010; 23 Yağmur *et al.*, 2011; 24 Lourenço and Simon, 2012; 25 Lourenco *et al.*, 2009b; 26 Kovařík 2003; 27 Vachon, 1949; 28 El-Hennawy, 1988; 29 Levy *et al.*, 1973; 30 Lourenço, 1999; 31 Kovařík, 2007; 32 Werner, 1902; 33 Vachon and Stockmann, 1968; 34 Lourenco and Duhem, 2007; 35 Simon 1910; 36 Vachon and Kinzelbach, 1987; 37 Lourenco and Leguin 2011; 38 Boehm 1912; 39 Vachon, 1952; 40 El-Hennawy, 2003; 41 Probst, 1973; 42 El-Hennawy, 2008; 43 Fet *et al.*, 2003b; 44 Lourenco, 2011; 45 Badry, 2013

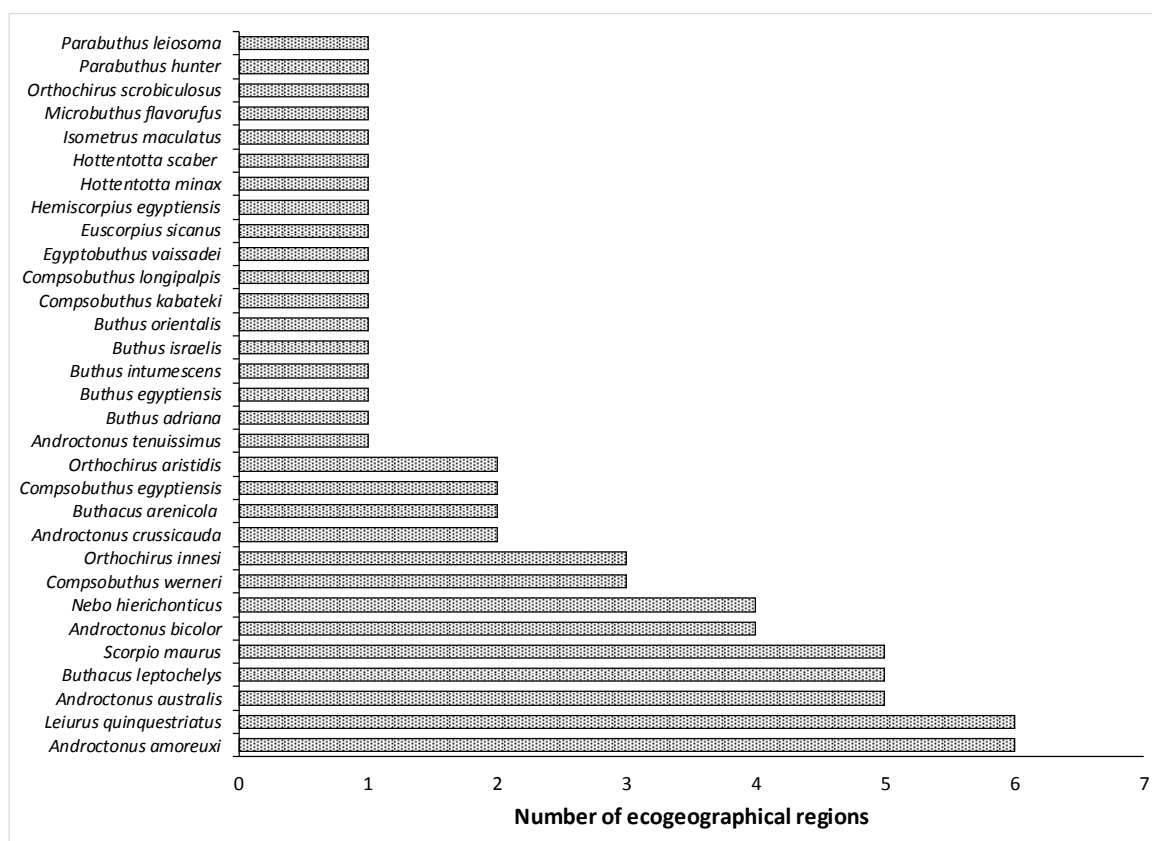


Figure 3. Occurrence of species in available six eco-geographical regions in Egypt.

Corridors, with less severe environmental conditions; penetrate some of the arid and extremely arid regions of northeastern Sahara, linking some of its habitable areas to adjacent, less arid regions. These corridors allow variable levels of faunal exchange between the regions they link. The structure of the present-day scorpion fauna appears to be closely linked to the history of evolution and extinction of these corridors. Two major terrestrial corridors connecting northeastern Sahara to less arid regions may be recognized in Egypt. These are the Nile River and its flood plain, which connect North Africa and the Mediterranean basin to the Afrotropical region, and the climatically mild, Mediterranean coastal belt, which links North Africa to the Levant and the mesic part of the Palearctic region. The Nile Valley, since its connection to the African tropics during the late Pleistocene (Said, 1993), has acted as a major faunal dispersal corridor between the Palearctic Mediterranean basin and the Afrotropical region. In addition, the Nile

Valley seems to have played a pivotal role in structuring the fauna of Egypt in two more ways. First, the Nile and its well-watered flood plain have created an island of non-xeric habitats in the extremely arid desert of the northeastern Sahara. Fauna inhabiting this riverine oasis is typical of mesic habitats and are incapable of penetrating the desert to the east or west of the Nile Valley (Saleh and Basuony, 2014). Second, the Nile Valley cuts across that part of the Sahara creating a typical, knife-like ecological barrier that separates desert-adapted species to the east and the west. The importance of such a formidable zoogeographical barrier is even more evident when one considers how the Nile Delta contributes to the effectiveness of the Isthmus of Suez as a barrier to the flow of fauna between Asia and Africa (Saleh and Basuony, 1998; Saleh *et al.*, 2003).

Palearctic, non-xeric fauna may have also dispersed to North Africa via the narrow

corridor of the Mediterranean coastal belt, which because of the maritime influence of the Mediterranean has a relatively milder climate than the extremely arid Saharan hinterland. The climate of that belt varies from one place to another, but it becomes particularly arid in Egypt. Species using this coastal route may disperse westwards from the Levant to the Sinai, but are often stopped at the arid Mediterranean coast of Northern Sinai. Species capable of continuing along this route will finally stop at the Isthmus of Suez and Nile Delta with their drastically different environmental conditions. Fauna dispersing eastwards from the more humid areas of the African coast of the Mediterranean is faced with the progressively intensifying aridity in eastern Libya and Egypt, which seem to halt further progress of many species in that direction. For other eastward dispersing species, the Nile Delta will eventually stop further progress.

The present results show that 18 of the 31 species with known collection localities occur in single eco-geographical regions. Furthermore, 12 of these are known from single collection localities (Table, 2) and most are known from a very small number of specimens, in some cases, even a single specimen. Although this may appear to reflect ecological restriction to a particular type of eco-geographical region, it more strongly suggests inadequate distributional data rather than actual ecological restriction. Only six of these seemingly restricted species, were recorded from more than one locality within their apparent restriction eco-geographical region. These are *Androctonus tenuissimus*, *Buthus adrianae* and *Buthus orientalis*, which were collected from far apart WMCD localities, *Buthus intumescens* and *Parabuthus leiosoma* which were both collected from EID and *Orthochirus scrobiculosus*, which was recorded from several localities in South Sinai. The actual geographical distribution of these 12 species with single collection localities remains virtually unknown. On the other hand, seven species (*Androctonus amoreuxi*, *A. australis*, *A.*

bicolor, *Buthacus leptochelys*, *Leiurus quinquestraiatus*, *Nebo hierichonticus* and *Scorpio maurus*) are widespread throughout the country occurring in four or more of the six eco-geographical regions and appear to be habitat generalists (Mirshamsi, 2011). Most of these species have wide general distribution across North Africa and the Middle East.

The dendrogram in Figure 4 shows the results of cluster analysis of the scorpion faunal composition of different eco-geographical regions in Egypt. The dendrogram shows two main clusters. One consisting of the scorpion fauna west of the Nile (WMCD and WID) in addition to that of the Mediterranean coastal deserts of the Sinai Peninsula SMCD). The other cluster encompasses the scorpion fauna of the Nile Valley and Delta and regions to the east of it (EID and SID). In the first cluster, the dendrogram shows the clustering of the SMCD and WID together and away from the WMCD. The scorpion fauna of these two predominantly hyper-arid regions is mostly made of widely distributed species with wide ecological tolerance, in addition to those that are particularly adapted to extreme desert conditions. For the WID, five of the eight recorded species are widespread in Egypt, occurring in at least five of the six surveyed eco-geographical regions (Table 2). The same widespread species, except *Scorpio maurus* also occur in the SMCD. Two of the three WID species (*Buthus egyptiensis*, and *Compsobuthus egyptienness*) are only known from the oases of that desert. The two species were only known from their type locality in Siwa Oasis (Lourenço *et al.*, 2009b; Lourenço & Cloudsley-Thompson, 2012) but our collection expanded the known range of *Compsobuthus egyptienness* to cover all oases of the Egyptian Western Desert, including the riverine oasis of Faiyum which is linked to the Nile Valley via a branch of the Nile River. The third species *Orthochirus innesi*, is somewhat widespread occurring in addition to the WID, in the WMCD and EID east of the Nile River. The know range of that species extends west into

Libya, Algeria and Tunisia (Lourenço & Leguin, 2011).

The disjunct pattern of distribution of the WID habitats and its scorpion fauna suggest that the present-day isolated populations of different scorpion species represents relicts of a wider distribution during the early Holocene when aridity was less intense in North Africa (Roberts, 1998). When the present day hyper-arid conditions were reached around mid-Holocene, populations of these species were isolated in patches of suitable, mostly groundwater-based habitats that now characterize that extremely arid desert.

Similar to the SMCD, the WID scorpion fauna consists mostly of widespread species (Table 2). Two species also occur in SID (*Androctonus crussicauda*, and *Nebo hierichonticus*) and one (*Egyptobuthus vaissadei*) is only known from its SMCD type locality (Lourenço, 1999), mostly groundwater-based habitats that now characterize that extremely arid desert. The WMCD scorpion fauna consists of 12 species and includes six of the seven widespread species (Table 2). Two predominantly North African species; *Orthochirus innesi* and *Buthus adrianae* occur in WMCD with ranges extending into the inland desert both east of the Nile River for the former, and the EID and the Sinai Peninsula for the latter. Four species (*Androctonus crussicauda*, *Buthus adrianae*, *Buthus orientalis* and *Euscorpis sicanus*) are only known in Egypt from this eco-geographical region. *Androctonus crussicauda* is only known from its WMCD type localities while the other three are known from other areas outside Egypt.

The second main cluster of the dendrogram (Figure 4), shows the close clustering of NVD and regions to the east (EID and SID). Although the Gulf of Suez now separates Southern Sinai from the Eastern Desert, this separation was not always present. During drier periods of the Pleistocene, the Gulf of Suez had a much-reduced area and the Sinai Peninsula and the Eastern Desert formed one, largely

continuous arid mountain zone (Por, 1971; Derricourt, 2005). The connection allowed uninterrupted faunal exchange between the now separated regions. Furthermore, the ecological settings of the two regions continued to be generally similar. Habitats of these two predominantly hilly regions are essentially restricted to the drainage lines. Wadis draining large watersheds in these arid or even hyper-arid regions support much more luxuriant vegetation cover than the surrounding areas and often support relatively diverse animal communities (Saleh, 1993). Many of the wadis drain into the Nile and support a continuum between the xeric habitats and biota of desert wadis and the well-watered Nile Valley riverine oasis.

The largest number of species are recorded from the Eastern Desert (Table 2). Of the 15 species recorded from that region, seven are widespread species occurring in at least 4 of the six eco-geographical regions, and have a relatively wide distribution in North Africa and the Middle East. Four species (*Buthus intumescens*, *Hottentotta scaber*, *Microbuthus flavorufus*, and *Parabuthus leiosoma*) are only restricted to that region and the remaining four species occur in some of the other eco-geographical regions of Egypt. The Nile Valley and Delta have 15 species, seven of which are widespread species and five are known in Egypt only from that eco-geographical region (*Compsobuthus kabateki*, *Hottentotta minax*, *Isometrus maculatus*, *Parabuthus hunteri*, and *Hemiscorpius egyptiensis*). Both *Compsobuthus kabateki* and *Hemiscorpius egyptiensis* are only known from their type localities in upper Nile Valley of Egypt (Kovařík, 2003a; Lourenço, 2011). *Hottentotta minax* is only from the Cairo area, most likely in the Nile Valley and is widespread into sub-Saharan Africa. Also, *Isometrus maculatus* is only known from its collection locality referred to as Port Said and Alexandria (Simon, 1910). In addition, *Parabuthus hunteri* is only known from the Nile Valley of Egypt and Sudan (Kaltsas *et al.*, 2008).

SID has nine species, including four widespread species. Three species (*Buthus israelis*, *Compsobuthus longipalpis* and *Orthochirus scrobiculosus*) are known in Egypt only from this ecoregion and relatively small area in the deserts of Jordan and Palestine. *Compsobuthus weneri* is a widespread species in Africa and southwestern Asia is only known in Egypt from SID, EID and NVD. *Androctonus crussicauda* occurs only in southern and northern Sinai and Egypt, but has a wider range in Asia (Kaltsas *et al.*, 2008). Other than the widespread species that seem to form a group of habitat generalists (Mirshamsi, 2011), the scorpion fauna of the Nile Valley and Delta includes only one species that also inhabits the inland Western Desert (*Compsobuthus egyptiensis*) and two that also occur in the Eastern Desert (*Compsobuthus weneri* and *Orthochirus aristidis*).

The above analysis shows that the distribution and composition of scorpion fauna of Egypt is dictated by ecological history of the region as well as by present-day habitat features. Major, but relatively recent land form features that now separate some eco-geographical regions appear to have limited influence on the present-day faunal composition and distribution patterns. The Nile Delta, for instance, is a relatively recent geomorphologic feature that interrupts the Levant - North Africa Mediterranean maritime exchange corridor for animals adapted to mild desert conditions since Late Pleistocene (Said, 1993). Yet fauna of the Mediterranean coastal belt east and west of the Nile Delta show some notable similarity that reflects the long, Plio-Pleistocene connection that predates the formation of the present-day Nile Delta (Said, 1990; 1993). Similarly, scorpion faunas of wadis in hilly areas east and west of the Gulf of Suez (SID and EID), are remarkably close. This may also reflect the frequent connection between the two regions during successive periods when the Gulf of Suez was fragmented or even disappeared altogether (Said, 1990; Derricourt, 2005;). The Nile River and its densely vegetated flood plain seem to also

separate faunas of inland habitats into that of the highly disjunct populations of the hyper-arid, inland Western Desert, and that of the wadis, which enjoy locally less arid habitats in the Eastern Desert and the Southern Sinai.

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