Archives of Razi Institute, Vol. 76, No. 1 (2021) 149-160

DOI: 10.22092/ari.2019.127114.1370

Original Article

Species Composition and Spatial Distribution of Scorpions Based on Eco-Environmental Variables in Provinces Along with the Oman Sea and the Persian Gulf in Iran: A GIS-Based Approach

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Received 17 July 2019; Accepted 17 November 2019
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Abstract

Scorpions are venomous arachnids with major medical health importance in Iran, specifically in the Southwest. In total, three families of scorpions, including *Scorpionidae*, *Hemiscorpiidae*, and *Buthidae* were reported in Iran. This study was conducted on scorpion ecology to determine the species composition and the dispersion of scorpions based on the ecological and environmental variables in combination with the Geographic Information System (GIS) in Khuzestan, Hormozgan, and Bushehr Provinces along with the Oman Sea and the Persian Gulf in Iran. Scorpions were collected from Hormozgan, Khuzestan, and Bushehr Provinces, Iran using the Ultra Violet light. The specimens were then identified according to their morphological characters utilizing reliable keys. To determine the relationship between the eco-environmental variables and the spatial distribution of species, the GPS points of the collected scorpions were recorded, and the scorpion shapefile was overlaid on digital elevation model, slope, land use, temperature, rainfall, soil texture, and bioclimatic maps. Totally, 25 specimens were reported in three families of *Scorpionidae*, *Hemiscorpiidae*, and *Buthidae*. Furthermore, *Razianus zarudnyi*, *Androctonus crassicauda*, *Buthacus macrocentrus*, *Mesobuthus eupeus phillipsii*, *Odontobuthus bidentatus*, and *Hemiscorpius lepturus* were the common species collected from Hormozgan, Khuzestan, and Bushehr Provinces, Iran. The results of the current study showed that a large number of species preferred the sand texture due to ecomorphological adaptation. Moreover, the poor rangeland vegetation cover was preferred by the majority of the scorpion species, including *S. maurus townsendi*. According to the results, the combination of the ecological factors related to the suitable habitat of different species of scorpion and GIS will provide the dispersal areas of each species. Furthermore, such databases can be comprehensive and valuable guides for health authorities to reduce and manage scorpion envenomation.

Keywords: Fauna, GIS, Iran, Scorpion, Spatial distribution

Composition des Espèces et Répartition Spatiale des Scorpions en Fonction des Variables Écoenvironnementales dans les Provinces Côtières de la Mer D'Oman et du Golfe Persique en Iran: Une Approche Basée sur le SIG

Résumé: Les scorpions sont des arachnides venimeux ayant une importance médicale majeure en Iran, en particulier dans le sud-ouest. Au total, trois familles de scorpions, dont des *Scorpionidae*, des *Hemiscorpiidae* et des *Buthidae*, ont été signalées en Iran. Cette étude a été menée sur l'écologie des scorpions pour déterminer la

composition des espèces et la dispersion des scorpions en fonction des variables écologiques et environnementales en combinaison avec le système d'information géographique (SIG) dans les provinces côtières de la mer d'Oman et du golfe Persique en Iran, les provinces de Khuzestan, Hormozgan et Bushehr. Les scorpions ont été collectés dans les provinces de Hormozgan, Khuzestan et Bushehr, en Iran, à l'aide de la lumière ultraviolette. Les spécimens ont ensuite été identifiés en fonction de leurs caractères morphologiques à l'aide de clés fiables. Pour déterminer la relation entre les variables écoenvironnementales et la distribution spatiale des espèces, les points GPS des scorpions collectés ont été enregistrés et le fichier de formes de scorpion a été superposé sur le modèle numérique d'élévation, la pente, l'utilisation des terres, la température, les précipitations, la texture du sol et des cartes bioclimatiques. Au total, 25 spécimens ont été signalés dans trois familles de *Scorpionidae*, *Hemiscorpiidae* et *Buthidae*. En outre, *Razianus zarudnyi*, *Androctonus crassicauda*, *Buthacus macrocentrus*, *Mesobuthus eupeus phillipsii*, *Odontobuthus bidentatus* et Hemiscorpius *lepturus* étaient les espèces communes récoltées dans les provinces de Hormozgan, Khuzestan et Bushehr, en Iran. Les résultats de la présente étude ont montré qu'un grand nombre d'espèces préféraient la texture du sable en raison de l'adaptation écomorphologique. En outre, la faible couverture végétale des parcours a été préférée par la majorité des espèces de scorpions, y compris *S. maurus townsendi*. Selon les résultats, la combinaison des facteurs écologiques liés à l'habitat convenable de différentes espèces de scorpion et du SIG fournira les zones de dispersion de chaque espèce. En outre, ces bases de données peuvent être des guides complets et précieux pour les autorités sanitaires afin de réduire et de gérer l'envenimation par les scorpions.

Mots-clés: Faune, SIG, Iran, Scorpion, distribution spatiale

Introduction

Scorpions are the medically important predatory arachnids that belong to the phylum Arthropoda and subphylum Chelicerata. In total, three families of scorpions, including *Scorpionidae*, *Hemiscorpiidae*, and *Buthidae*, as well as 17 genera and 64 species of scorpions have been reported in Iran up to 2017(Motevalli Haghi and Dehghani, 2017). This nocturnal animal inhabits the warm and dry environment (Rafizadeh et al., 2013). Furthermore, these terrestrial arthropods are so rich exactly in Central and South parts of Iran due to the climate condition in these areas (Sedaghat et al., 2012). Scorpion envenomation is a major health problem specifically in the Southwest of the country (Shahbazzadeh et al., 2009). Most envenomation and death rates were reported in Khuzestan Province, Iran, because of the climate, low altitude, and socio-economic structure (Ozkan and Kat, 2005). The incidence rate of scorpion envenomation is about 5.59 in 100,000 inhabitants in Iran. Additionally, most cases of scorpion sting were 541 cases per 100,000 population in Khuzestan Province, Iran, followed by Hormozgan, Ilam, and Bushehr Provinces that included the rates of 153.9, 127, and 123 cases per 100,000 population in descending order during 2009 (Rafizadeh et al., 2013).

The nature of substratum and the substratum specialization are two defined concepts (Lamoral, 1979) that refer to soil hardness and texture, as well as ground physiognomy and vegetation cover (Prendini, 2005). The topography is a barrier to scorpion distribution (Koch, 1977). The relationship between substrate and abundance of scorpion has been confirmed in some studies (Cala-Riquelme and Colombo, 2011). Ecomorphotypes are defined as any morphological modification in scorpions that are identified in four types, such as fossorial, psammophilous, errant, and lithophilous (Mc Cormick and Polis, 1990). Furthermore, slope, altitude, rock cover, vegetation cover, temperature, and humidity are effective factors in the structure of scorpion (Cloudsley-Thompson, 1975; Gefen and Ar, 2006; Dehghani et al., 2014; Foord et al., 2015).

Geographical Information System (GIS) applications have been used for predicting various animals' habitats. The GIS approaches based on the environmental data are practical and powerful tools to determine the spatial

distribution of species (Rotenberry et al., 2006). Moreover, the species distribution models and predictive species dispersal maps in the GIS-based researches were used as decision-making tools for explanation and understanding the cause of the organism distribution in the environment (Miller, 2010). Environmental suitability maps are the visualizing pattern used to determine the dispersion process of species, help the epidemiological surveillance of these venomous arthropods that are at the risk group (Brites-Neto and Duarte, 2015), and predict the possibility of scorpion presence and envenomation hazard (El Hidan et al., 2017).

Insufficient knowledge about the geographical distribution of the scorpion species and their habitat characteristics justifies conducting the present study to determine species composition and the dispersion of scorpions based on the ecological and environmental variables in combination with GIS in Khuzestan, Hormozgan, and Bushehr Provinces along with the Oman Sea and the Persian Gulf in Iran. Since no studies have been conducted on the ecology of scorpion in Iran, this study aimed to determine the effect of ecological features on the distribution of scorpion in three main provinces of Iran with scorpion history.

Material and Methods

Study Areas

Khuzestan Province. Khuzestan Province (29° 57ˈN, 40° 47ˈE till 33° 00ˈN, 50° 33ˈE) is situated in the Southwest of the country, bordering Iraq and the Persian Gulf. Ahvaz is its capital with a 63,238 km^2 area. The climate is generally very hot and occasionally humid; however, it is colder and dry in winter. The maximum temperature of the province is up to 55ºC during summer. Khuzestan experiences many sandstorms, and the amount of winter rainfall ranges from 300 to 500 mm in the plains that increases in the mountains (Figure 1).

Bushehr Province. Bushehr province (27° 16ˈN, 50° 06ˈE till 30° 18ˈN, 52° 56ˈE) is located in the South of the country along with a long coastline on the Persian Gulf. Bushehr Province area is 27,653 km^2 with Bandar-e-Bushehr as its capital. The weather is very hot and humid on the Persian Gulf, while the other parts of the province are very hot and dry. This province has two seasons of winter and summer with a distinguishable climate. The minimum and maximum temperatures in the coldest and hottest months of the province were recorded at 6°C and 50°C, respectively (Figure 1).

Hormozgan Province. Hormozgan is located in the South of the country along with the Persian Gulf and the Oman Sea. The province with 70,697 km^2 area is 25° 24ˈN, 53° 41ˈE till 28° 57ˈN, 59° 15ˈE. Its capital is Bandar Abbas, and the coastline of the Persian Gulf with Hormozgan Province is 1000 Km (Figure 1).

Sampling. This cross-sectional study was conducted from 2013 to 2015. Scorpions were collected from Hormozgan, Khuzestan, and Bushehr Provinces using Ultra Violet light (Figure 1). All samples were transferred to the Razi Reference Laboratory of Scorpion Research and preserved in 70% ethanol. The specimens were then observed under a stereomicroscope and identified according to their morphological characters using reliable keys (Navidpour et al., 2008; Navidpour et al., 2013). It should be noted that the geographical locations of scorpions were recorded using GPS.

Data Preparation and Analysis. Climatic data were prepared from Meteorological Organization. Moreover, the temperature and precipitation maps were prepared using the Inverse Distance Weighted interpolation method. The shapefiles of the bioclimatic, slope, and land cover were prepared from the National Geography Organization of Iran. Furthermore, the GPS points of collected scorpions were used as a layer for analysis. Arc GIS 9.3 software was also utilized for preparing the spatial distribution map of scorpions in the study area. All data layers were classified, and the GIS layer containing scorpion data was transferred to Arc Map which was the main component of Arc GIS software for geospatial processing. To determine species dispersion and habitat characterization, the classified

environmental, topographical, and ecological maps were overlaid in this study.

Results

Totally, 25 specimens were reported in three families of *Scorpionidae*, *Hemiscorpiidae*, and *Buthidae*. However, the majority of the scorpion species belonged to *Buthidae* family. Scorpion fauna, such as *O. doriae*, *H. salcyi*, *A. crassicauda*, and *M. eupeus* are important in medicines that are implicated in the envenoming of humans (Jalali et al., 2010). *Razianus zarudnyi*, *A. crassicauda*, *B. macrocentrus*, *M.eupeus phillipsii*, *O. bidentatus*, and *H. lepturus* were the common species collected from Hormozgan, Khuzestan, and Bushehr Provinces, Iran (Table1).

Bushehr Province. Figure 2a shows the spatial distribution of scorpions in the study area. Ganaveh and Tangestan counties had the most scorpion species diversities among others. Table 2 tabulates the spatial distribution of scorpions concerning environmental variables. The majority of the species were observed in 24°C (Figure 2b), and the rainfall map was divided into three classes. *Buthacus macrocentrus* was collected in 250 and 350 mm; however, other species were only found in the area with 250 mm rainfall (Figure 2c). The majority of species were observed in the rangeland (poor vegetation) land cover. In fact, *Compsobuthus persicus* and *O. farzanpay* were found in salty lands as land cover.

The result of this study determined that most of the species preferred sandy soil texture for living. *Orthochirus iranus* and *O. farzanpay* had no preference, and they were collected from sandy, sandy-loamy, loamy-clay, and clay-loamy-sandy soil textures. As shown in Table 2, most of the scorpion species are observed in arid bioclimatic, while *B. macrocentrus* was collected from three types of bioclimatic, including arid, semi, and ultra-arid. In two classes of 30-45° and 45-60° slopes, only two species of *O. bidentatus* and *B. macrocentrus* were found, respectively.

Hormozgan Province. The highest diversity of scorpion species was recorded in Bandar-Lengeh County (Figure 3a). The collected scorpion species in Hormozgan, Iran, is shown in Table 1. The greatest number of species was found in the areas with 23-24°C temperature, except for *O. farzanpayi*, *R. zarundnyi*, and *H. lepturus* (Figure 3b). All species lived in a 2-5° slope; however, *M. eupeus persicus* were collected from a 45° slope. The maximum distribution of scorpion was in the rainfall of 200-250 mm, whereas *O. farzanpayi* was observed in the rainfall of 150-200 mm (Figure 3c). Table 3 summarizes the distribution of each species in various classes of eco-environmental variables. *Orthochirus tirgari* was the only species that was collected from ultra-arid bioclimatic. Moreover, *Orthochirus stockwelli*, *M. eupeus phillipsii*, *S. gracilis*, and *H. acanthocercus* were observed in three classes of soil texture, including sandy, loam-clay, and clay-loam-sandy. Rock as land cover was a habitat for *R. zarudnyi*, *O. stockwelli*, *O. varius*, *M. eupeus persicus*, *S. gracilis*, and *H. acanthocercus*. Totally, the collected scorpions preferred 2-5° slopes, while *H. acanthocercus* was the only species that lived on the slope of 15-20°.

Khuzestan Province. The species composition of the scorpion is shown in Table 1, and Figure 4a illustrates their distribution in the province. Moreover, the highest scorpion species diversity was determined in Ahvaz, Iran. Scorpion dispersal regarding eco-environmental factors was reported in Table 4. All of the specimens were adapted to the temperature of 20-22.5°C; however, some species showed more adaptation in the range of 17.5-20°C (Figure 4b). The bioclimatic zone, including arid, was the favorite zone for the species of *H. saulcyi*, *A. susanae*, and *V. iranus*. Moreover, *H. khoozestanus* was found in the semi-arid zones, while *H. zagrosensis* lived in the Mediterranean bioclimatic.

All of the scorpion species, except for *H. khoozestanus* were found in the clay-loamy-sandy soil texture. *Mesobuthus eupeus philipsii* was the only species in salty lands, while *Razianus zarudnyi*, *C. jakesi*, *M. eupeus phillipsii*, *O. bidentatus*, and *Hemiscorpius lepturus* were observed in barren lands.

The majority of scorpion species in Khuzestan, Iran, including *Orthochirus iranus*, *C. matthiesseni*, *H. saulcyi*, *A. crassicauda*, *O. bidentatus*, *H. khoozsetanus*, *H. zagrosensis*, and *H. lepturus* were observed in the habitat with rainfall of 500-600 mm. On the other hand, *M. eupeus phillipsii*, *R. zarudnyi*, and *Hemiscorpius lepturus* were in the area with 150 mm rainfall (Figure 4c). All scorpion species were collected from the slope of 2-10°, whereas *H. khoozestanus* was observed in the slope of 30-45°.

Table 1. Species composition of scorpions in the study area

Species	Province	Bushehr	Khuzestan	Hormozgan
Scorpio maurus townsendi		✶	✶	
Razianus zarudnyi		✶	✶	✶
Compsobuthus matthiesseni		✶	✶	
Compsobuthus persicus		✶		
Compsobuthus jakesi			✶	
Orthochirus iranus		✶	✶	
Orthochirus stockwelli		✶		✶
Orthochirus farzanpayi		✶		✶
Orthochirus varius				✶
Orthochirus tirgari				✶
Androctonus crassicauda		✶	✶	✶
Buthacus macrocentrus		✶	✶	✶
Mesobuthus eupeus persicus				✶
Mesobuthus eupeus phillipsii		✶	✶	✶
Odontobuthus doriae				✶
Odontobuthus bidentatus		✶	✶	✶
Polisius persicus				✶
Sassanidothus gracilis				✶
Hottentotta saulcyi			✶	
Hottentotta khoozestanus			✶	
Hottentotta zagrosensis			✶	
Vachoniolus iranus			✶	
Apistobuthus susanae			✶	
Hemiscorpius acanthocercus				✶
Hemiscorpius lepturus		✶	✶	✶

Table 2. Collected scorpions based on environmental variables, Bushehr Province, Iran

Parameters	Class	Species											
		Scorpio maurus townsendi	***Razianus zarudnyi***	***Compsobuthus matthiesseni***	***Compsobuthus persicus***	***Orthochirus iranus***	***Orthochirus stockwelli***	***Orthochirus farzanpayi***	***Androctonus crassicauda***	***Buthacus macrocentrus***	***Mesobuthus eupeus phillipsii***	***Odontobuthus bidentatus***	***Hemiscorpius lepturus***
Bioclimatic	Arid	✶	✶	✶	✶	✶	✶	✶	✶	✶	✶	✶	✶
	Semi-arid									✶			
	Ultra-arid	✶				✶	✶		✶	✶	✶	✶	
Soil texture	Sandy	✶	✶	✶	✶	✶	✶	✶		✶	✶	✶	✶
	Sandy-loamy	✶			✶	✶		✶	✶			✶	
	Loamy-clay		✶			✶		✶	✶	✶	✶		
	Clay-loamy-sandy					✶	✶	✶	✶	✶	✶	✶	
Land cover	Poor rangeland vegetation	✶	✶	✶	✶	✶	✶	✶	✶	✶	✶	✶	✶
	Shrubbery and Chaparral					✶	✶						
	Rainfed agriculture		✶		✶			✶			✶	✶	✶
	Salty lands				✶			✶					
	Island										✶	✶	
	Barren										✶		
Slope	0-2°	✶			✶	✶		✶	✶	✶		✶	
	2-5°	✶	✶		✶		✶	✶	✶		✶	✶	✶
	5-10°	✶	✶	✶		✶	✶		✶	✶	✶	✶	✶
	30-45°											✶	
	45-60°									✶			

Table 3. Collected scorpions based on eco-environmental variables, Hormozgan Province, Iran

Parameters	Class	Species															
		Razianus zarudnyi	***Orthochirus stockwelli***	***Orthochirus farzanpayi***	***Orthochirus varius***	***Androctonus crassicauda***	***Buthacus macrocentrus***	***Mesobuthus eupeus***	***Mesobuthus eupeus***	***Odontobuthus tavighi***	***Odontobuthus doriae***	***Odontobuthus bidentatus***	***Polisius persicus***	***Sassanidothus gracilis***	***Hemiscorvius***	***Hemiscorpius lepturus***
Bioclimatic	Arid							✶	✶	✶	✶	✶			✶	✶
	Ultra-arid	✶	✶	✶	✶	✶	✶	✶	✶		✶	✶	✶	✶	✶	✶
Soil texture	Sandy	✶	✶				✶	✶	✶			✶	✶	✶	✶	✶
	Loamy-clay		✶			✶	✶		✶	✶		✶		✶	✶	
	Clay-loamy-sandy	✶	✶	✶	✶			✶	✶		✶			✶	✶	✶
Land cover	Rangeland(poor vegetation)	✶	✶	✶	✶	✶	✶	✶	✶		✶	✶		✶	✶	✶
	Rock	✶	✶		✶			✶						✶	✶	
	Rainfed agriculture							✶	✶			✶	✶			
	Tree landscape	✶	✶				✶	✶	✶		✶	✶		✶	✶	
	Forage planning hands					✶		✶		✶				✶		
	Barren		✶			✶	✶	✶	✶			✶		✶		
Slope	0-2°							✶				✶				
	2-5°	✶	✶	✶	✶	✶	✶	✶	✶	✶	✶	✶	✶	✶	✶	✶
	5-10°	✶	✶			✶		✶				✶				✶
	15-20°														✶	
	20-30°							✶								✶
	30-45°	✶			✶			✶						✶		

Table 4. Collected scorpions based on environmental variables, Khuzestan Province, Iran

Parameters	Class	Species														
		Scorpio maurus fuscopilosus	*Razianus zarudnyi*	*Compsobuthus*	*Compsobuthus iakesi*	*Orthochirus iranus*	*Hottentotta saulcyi*	*Hottentotta khoozestanus*	*Hottentotta zagrosensis*	*Apistobuthus susanae*	*Vachoniolus iranus*	*Androctonus crassicauda*	*Buthacus macrocentrus*	*Mesobuthus eupeus*	*Odontobuthus bidentatus*	*Hemiscorpius lepturus*
Bioclimatic	Arid	✶	✶	✶	✶	✶	✶			✶	✶	✶	✶	✶	✶	✶
	Semi-arid		✶		✶			✶				✶	✶	✶	✶	✶
	Ultra-arid					✶										
	Mediterranean		✶	✶	✶	✶			✶							
Soil texture	Sandy	✶	✶	✶	✶			✶					✶	✶		✶
	Sandy-loamy													✶		
	Loamy-clay				✶	✶				✶			✶	✶		
	Clay-loamy-sandy	✶	✶	✶	✶	✶	✶		✶	✶	✶	✶	✶	✶	✶	✶
Land cover	Rangeland (poor vegetation)	✶	✶	✶	✶	✶	✶		✶	✶		✶	✶		✶	✶
	Rangeland (medium vegetation)		✶		✶	✶				✶	✶	✶	✶	✶		✶
	Rainfed Agriculture	✶		✶	✶	✶	✶		✶	✶		✶	✶		✶	
	Salty lands													✶		
	Barren		✶		✶									✶	✶	✶
	Jungle with low density							✶								
	Garden			✶	✶				✶							
Slope	0-2°				✶	✶				✶	✶	✶	✶	✶	✶	✶
	2-5°	✶	✶	✶	✶	✶				✶	✶	✶	✶	✶		✶
	5-10°		✶		✶		✶		✶			✶	✶	✶	✶	✶
	10-15°		✶	✶	✶	✶			✶				✶		✶	
	30-45°							✶								

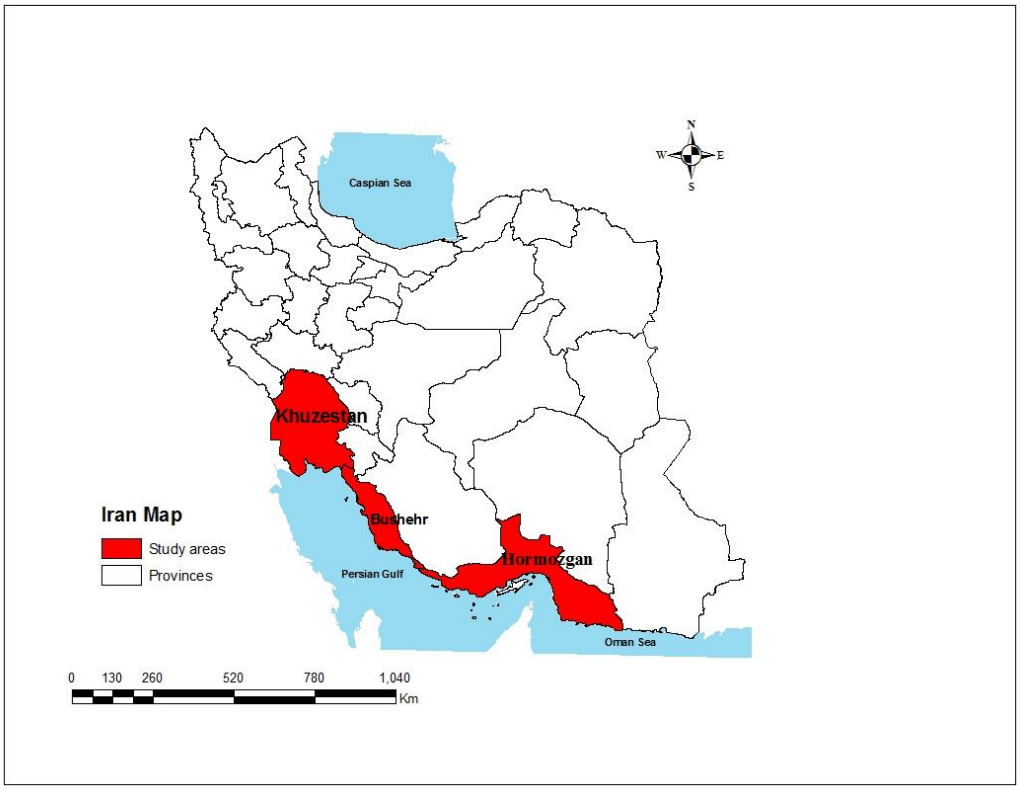

Figure 1. Study areas in Iran

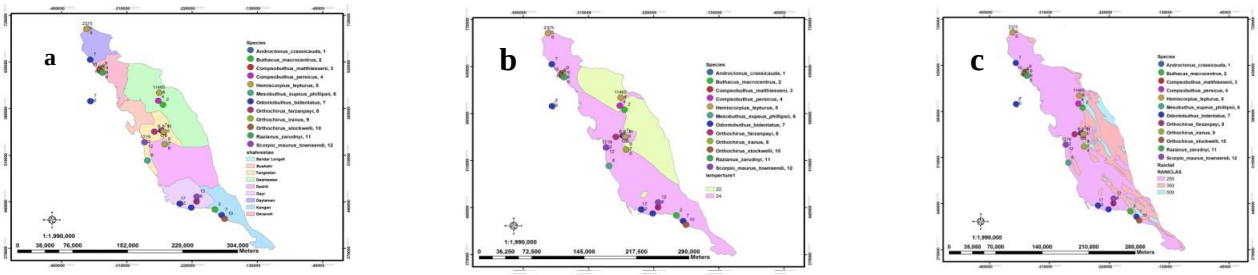

Figure 2. Environmental factor and scorpion distribution in Bushehr Province, Iran. a: Spatial distribution, b: Map of temperature, c: Map of rainfall

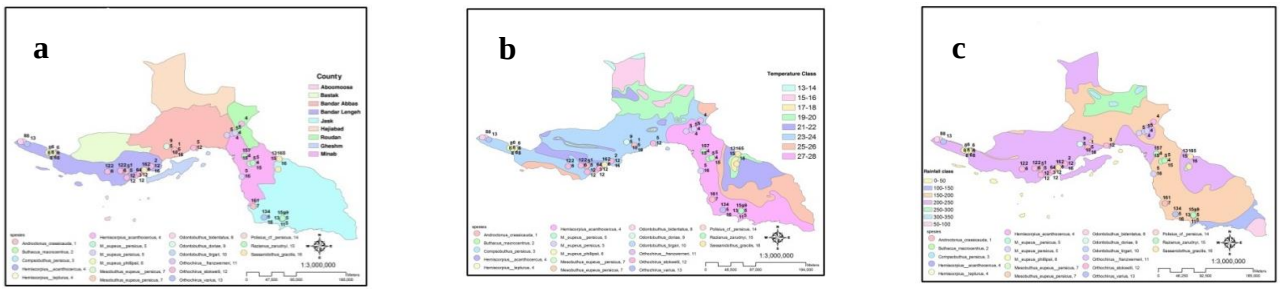

Figure 3. Environmental factor and scorpion distribution in Hormozgan Province, Iran. a: Spatial distribution, b: Map of temperature, c: Map of rainfall

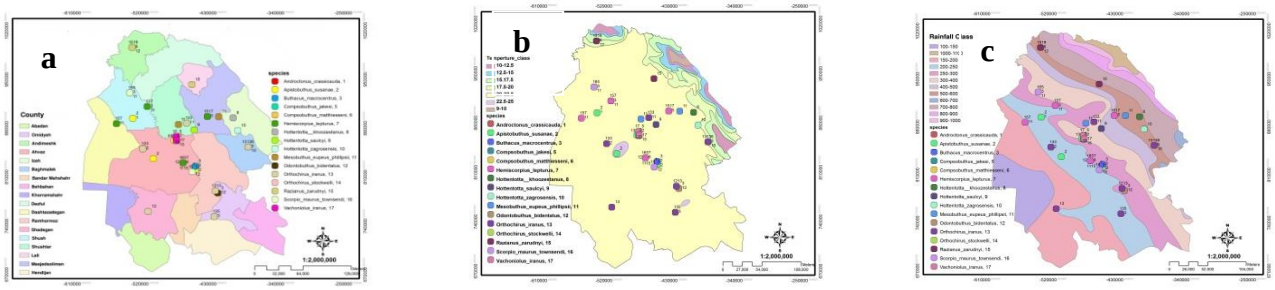

Figure 4. Environmental factor and scorpion distribution in Khuzestan Province, Iran. a: Spatial distribution, b: Map of temperature, c: Map of rainfall

Discussion

This study determined the scorpion species composition and focused on the relationship between environmental variables and distribution of the scorpions in Khuzestan, Bushehr, and Hormozgan Provinces, Iran. The previous studies in Iran only determined the fauna composition of scorpions or mapped the species in restricted areas (Mozaffari et al., 2013; Sharifinia et al., 2017). Scorpions are mostly known as important health concerns in tropical and subtropical areas due to scorpion envenomation (Bawaskar and Bawaskar, 2012). Therefore, it is of significant importance to identify and understand their geographical distribution.

In this study, *Androctonus crassiacuda*, *B. macrocentrus*, *O. bidentatus*, *C. matthiesseni*, *C. persicus*, *R. zarudnyi*, *M. eupeus phillipssii*, *O. farzanpayi*, *O. iranus*, *O. stockwelli*, *S. maurus townsendi*, and *H. lepturus* were identified in Bushehr Province, Iran. In addition to the listed species, *C. jakesi* and *H. saulcyi* were confirmed as two species belonging to the fauna of the aforementioned province (Navidpour et al., 2008). According to the results of this study, 15 species, including O. *doriae*, *O. bidentatus*, *O. tavighiae*, *O.* farzanpayi, *M. eupeus phillipsii*, *M. eupeus persicus*, *O. varius*, *O. stockwelli*, *B. macrocentrus*, *P. persicus*, *A. crassicauda*, *H. lepturus*, *H. acanthocercus*, *R. zarudnyi*, and *S. gracilis* were recorded in Hormozgan Province, Iran. On the other hand, *Iranobuthus krali*, *Compsobuthus plutenkoi*, *C. persicus*, *Hemiscorpius enischnochela*, and *Nebo henjamicus* were reported in a previously conducted study (Navidpour et al., 2013). In this study, A. *crassicauda*, *A. susanae*, *B. macrocentrus*, *C. jakesi*, *C. matthiesseni*, *H. saulcyi*, *H. zagrosensis*, *H. khoozestanus*, *M. eupeus phillipsii*, *O. bidentatus*, *O. iranus*, *R. zarudnyi*, *V. iranus*, *S. maurus townsendi*, and *H. lepturus* were considered the species composition of scorpion in Khuzestan Province, Iran. Furthermore, *Compsobuthus garyi*, *H. schach*, *O. farzanpay*, and *O. stockwelli* were identified in the aforementioned province (Navidpour et al., 2008).

According to the results of this study, *R. zarudnyi*, *A. crassicauda*, *B. macrocentrus*, *M. eupeus phillipsii*, *O. bidentatus*, and *H. lepturus* were the common species in Khuzestan, Hormozgan, and Bushehr Provinces, Iran, indicating the high adaptation of these scorpions to choose the habitat. It is hypothesized that diversity in species composition is probably related to some eco-environmental factors, such as the amount of precipitation and substrate or inadequate sampling, which caused the missing of some species with narrow habitat circumstances.

Temperature, rainfall, elevation, slope, aspect, soil type, land use/cover, and ground physiognomy were introduced as effective ecological factors in scorpion distribution (Prendini, 2005). Determination of the effective ecological factors on scorpion distribution,

such as soil texture, land cover, temperature, rainfall, bioclimatic, and slope was also possible using GIS (El Hidan et al., 2017). The habitat of scorpions varies from the dry and hot deserts and mountains to the forests (Prendini, 2005). Furthermore, physical and biological factors are regarded as barriers to the distribution of scorpions due to the lack of access to suitable habitats (Burton, 1998). Substratum was reported as the most important factor in the determination of scorpion dispersal (Lamoral, 1979). In the present study, a large number of species were found in sand texture, while they were considered as *lithophilus* and errant scorpions. It is noteworthy to mention that the wide distribution of some scorpion species may be due to the eco-morphological adaptations. Vegetation structure and composition are obvious characters in organism distribution, such as temperature, soil texture, and rainfall (Druce et al., 2007). According to the results of a previously conducted study, *S. maurus* had a negative correlation with vegetation cover (Sadine et al., 2012). In the current study, poor rangeland vegetation cover was preferred by most of the scorpion species, including *S. maurus townsendi*. Moreover, the wide distribution of some species in the various classes of bioclimatic, soil texture, physiognomic surface, slope, rainfall, and temperature would be due to the high tolerance range of the organism.

Conclusion

According to the obtained results, the combination of the ecological factors related to the suitable habitat of different species of scorpion and the GIS-based approaches may determine dispersal areas of each scorpion species. Obviously, these databases can be comprehensive and valuable guides for health authorities to reduce and manage scorpionism and increase public health knowledge. Furthermore, an increase in the information related to the habitat and ecology of venomous arthropods is essential in order to collect the scorpions for pharmaceutical production and serum preparation. Finally, it is suggested that further studies be conducted in ecological niche modeling using Analytic Hierarchy Process, logistic regression, and Geographically Weighted Regression to predict the possibility of venomous scorpion presence.

Authors' Contribution

Study concept and design: Sh. N., E. J. and N. H. V.
Acquisition of data: E. J.
Analysis and interpretation of data: E. J.
Drafting of the manuscript: N. H. V.
Critical revision of the manuscript for important intellectual content: N. H. V., E. J. and Sh. N.
Statistical analysis: E. J.
Administrative, technical, and material support: N. H. V. and Sh. N.

Ethics

We hereby declare all ethical standards have been respected in preparation of the submitted article.

Conflict of Interest

The authors declare that they have no conflict of interest.

Grant Support

This study was funded by Razi Vaccine and Serum Research Institute. Grant no: 0181889068

Acknowledgment

The authors are grateful to Dr. Zahedi, Mr. Masihipour, and Mr. Habibzadeh .This study was funded and supported by Razi Vaccine and Serum Research Institute, Karaj, Iran (0181889068).

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