Acta Tropica 230 (2022) 106390

Contents lists available at ScienceDirect

Acta Tropica

journal homepage: www.elsevier.com/locate/actatropica

Detection of areas vulnerable to scorpionism and its association with environmental factors in São Paulo, Brazil

Alec Brian Lacerda [a], Camila Lorenz [a,*], Thiago Salomão Azevedo [b], Denise Maria Cândido [c], Fan Hui Wen [c], Luciano José Eloy [d], Francisco Chiaravalloti-Neto [a]

[a] Faculdade de Saúde Pública – Universidade De São Paulo, SP, Brazil
[b] Secretaria de Saúde do Município de Santa Bárbara d'Oeste – SP, Brazil
[c] Instituto Butantan, São Paulo, SP, Brazil
[d] Centro de Vigilância Epidemiológica "Prof. Alexandre Vranjac" São Paulo, SP, Brazil

ARTICLE INFO

Keywords:
Public health
Spatiotemporal
Epidemiology
Accident
Scorpion
Tityus serrulatus
Sting

ABSTRACT

Accidents caused by scorpions are considered a neglected condition and represent a major health problem in most tropical countries, especially for children and elderly people. In Brazil, scorpionism is recurrent in the southeast region, mainly in the state of São Paulo, due to the progressive increase in scorpions found in urban habitats. Thus, our study aimed to provide better insights into the geographic and epidemiological characteristics of scorpion envenomation in São Paulo state and identify the environmental factors that are associated with these accidents. This is an ecological and retrospective study with secondary data on scorpion accidents in the state of São Paulo from 2008 to 2018 obtained from the Notifiable Disease Information System. The SatScan software was used to identify the higher- and lower-risk spatiotemporal clusters. A total of 145,464 scorpion sting cases were recorded in the state of São Paulo, between 2008 and 2018; there was a four-fold increase in the incidence rate. Accidents occurred more frequently in the spring season, wherein higher-risk clusters were in the north and northwest regions of the state. High temperatures, low precipitation, and poor natural vegetation are associated with higher risk areas. Our study mapped vulnerable areas for scorpion accidents that can aid in the design of efficient public health policies, which should be intensified during the spring season.

1. Introduction

Scorpionism - a generic name given to accidents due to scorpions - occurs commonly in tropical and subtropical regions (Abroug et al., 2015), and represents a serious public health problem because of its high incidence and clinical relevance. It is estimated that in 2019, there were approximately 1.2 million accidents and 3500 annual deaths worldwide (SBMT, 2019). Scorpionism in Brazil has increased significantly in the last decade, leading the ranking of accidents caused by venomous animals in the country (Santos et al., 2016). Between 2007 and 2018, approximately 927,000 accidents due to scorpions have been reported, resulting in 972 deaths (MS, 2019; Furtado et al., 2020).

In Brazil, there are approximately 160 species of scorpions, but stings of medical importance are caused by only one genus, the *Tityus*. The species *Tityus serrulatus* (MS, 2019; Torrez et al., 2019) is responsible for the most severe cases and deaths (Cupo, 2015; Torrez et al., 2019). Its origin is not certain, but older records indicate the Brazilian state of Minas Gerais. However, it was found in 19 of the 27 Brazilian states (Torrez et al., 2019). The evolutionary process allowed a wide adaptation of several scorpion species, such *as T. serrulatus*, allowing greater dissemination that led them to occupy regions ranging from deserts to urbanized centers (Dabo et al., 2011; Santos et al., 2021).

In Brazil, scorpionism is recurrent in the southeast region, mainly in the state of São Paulo (SP), due to the progressive increase in scorpions found in urban habitats. Control measures and population management are based on the removal/collection of scorpions and modification of the environment in order to make it unfavorable to their occurrence, such as removing debris and garbage. Chemical control is not indicated, as scorpions can remain for long periods in natural or artificial shelters that prevent contact with the venom. In addition, they have the ability to remain with their pulmonary stigmas closed for a long period of time (MS, 2019). Spatial epidemiology allows identification of the frequency and distribution of higher-risk areas for scorpionism (Almeida et al., 2020), and these findings are essential for the prevention and

* Corresponding author at: USP: Universidade de Sao Paulo, Av Doutor Arnaldo 715, 05405-000 São Paulo, São Paulo, Brazil.
E-mail address: camilalorenz@usp.br (C. Lorenz).

https://doi.org/10.1016/j.actatropica.2022.106390
Received 22 January 2022; Received in revised form 28 February 2022; Accepted 28 February 2022
Available online 1 March 2022

surveillance of possible accidents (Araújo et al., 2016; Amado et al., 2021). Thus, the present study aimed to identify spatial, temporal, and space-time clusters with higher incidence rates of scorpionism in SP between 2008 and 2018, and investigate the environmental factors involved in the occurrence of these accidents.

2. Methods

This is an ecological and descriptive study using secondary data on scorpion accidents in 645 municipalities of SP reported between 2008 and 2018. These municipalities are aggregated in 17 regional health departments (RHDs) (Supplementary Material 1). The data on confirmed cases of scorpion accidents correspond to the notification forms of the Notifiable Diseases Information System of each municipality, available by the Center for Epidemiological Surveillance of SP. Demographic information and percentage of urbanization per municipality were acquired from the Brazilian Institute of Geography and Statistics (IBGE). Environmental information was obtained for each municipality: percentage of natural vegetation (Souza et al., 2022); average day temperature (°C); average night temperature (°C); thermal amplitude (difference between day and night temperature) (°C); and average precipitation (mm) (TRMM, 2011).

We obtained the incidence rates of scorpionism for the 17 RHDs of the state of São Paulo for each year of the study period. These incidences rates were standardized by age and sex using the population of the state of year of 2013. The purely spatial, space-time, purely temporal, seasonal, and spatial variations in the temporal trend clusters were determined using the scan statistics and SaTScan v10.0 program (Kulldorff, 2021). The purely spatial and space-time analyses identify the higher- and lower-risk clusters in space and time, respectively. The temporal and seasonal analyses identify the clusters of higher and lower risk only in time. The spatial variation in the temporal trends identifies the clusters with growth rates (or decreases) in and out of these clusters, and evaluates whether the difference between them is statistically significant. For the space-time and spatial variations in the temporal trend analysis, scorpion accidents were aggregated by year, whereas for temporal and seasonal analyses, the data were aggregated by month.

The maximum population size for the spatial scanning window was 5%, which was determined using the Gini index option in the SaTScan for the purely spatial analysis (Han et al., 2016). The maximum temporal length of the temporal scanning window is 50%. The p-value of the clusters was obtained through the Monte Carlo hypothesis test with 999 replications (Kulldorff, 2021). The level of significance was set at 5%. For the production of spatial, space-time, and spatial variation in the temporal trend clusters, the municipality of SP was ignored or disregarded from the cluster analysis due to its exacerbated population number, which would hamper the application of this method in particular; this, however, in no way invalidates the quality of the data presented in this study.

After identifying the higher- and lower-risk clusters for scorpionism in the purely spatial analysis, we statistically compared the values of demographic and environmental variables of the group of municipalities belonging to the higher-risk clusters with those of the lower-risk group. We created a spreadsheet in an Excel file for each one of these variables to insert their values, so that in the first and second columns we had, respectively, the values corresponding to the group of municipalities of higher-risk and lower-risk clusters. Then, we compared, for each demographic and environmental variable, the registered values in these two columns using the *t*-test for comparing means between two groups, assuming equivalent variances. The null hypothesis was that the means for the same variable were equal, with significance level equal to 5% (Oliveira, 2008).

Maps with significant clusters and respective relative risks (spatial and space-time scanning analyses) as well as the internal and external temporal trends (spatial variation in temporal trends analysis) were elaborated in the QGIS v3.16 program (QGIS Development Team, 2021).

3. Results

In 645 municipalities of SP, a total of 145,464 cases of scorpion accidents were confirmed between 2008 and 2018. In 2008, 5788 cases were reported, with an increase of 425% until 2018, with 30,394 confirmed cases. Since 2008, the incidence of scorpionism has gradually increased, starting with 14 cases per 100,000 inhabitant-years and reaching approximately 70 cases per 100,000 inhabitant-years in 2018, corresponding to an increase of 378.5% in the period (see Supplementary Material 2). This advance in the incidence rates corresponded, in different levels, to the increase in the incidences in almost all RHDs of the state of São Paulo (Supplementary Material 2). The main species found in São Paulo/Brazil was *Tityus serrulatus*.

In the purely temporal aspect (Fig. 1A), a higher-risk cluster was identified in the period from September 2015 to December 2018 (relative risk [RR] = 2.48), while a lower-risk cluster was present in the initial period, from January 2008 to July s (RR = 0.42). The higher-risk months identified in the seasonal analysis for scorpion accidents were from September to December (spring season), with an RR of 1.38 (Fig. 1B). A lower-risk period from March to August (RR = 0.73) was also identified (Fig. 1B).

Regarding the purely spatial analysis of the total accidents, four and eight statistically significant higher- and lower-risk spatial clusters were identified, respectively. Throughout the analyzed period, the two highest-risk areas were concentrated in the northwestern and north regions of the state, with RR of 6.06 and 4.80, respectively, and localized mainly on the Araçatuba, Barretos, and São José do Rio Preto RHDs (Fig. 2A and Supplementary Material 1). The other two secondary clusters of higher risk were located in the northeast and central east of the state. All lower-risk clusters were located in the eastern part of the state (Fig. 2A).

The statistical comparison of demographic and environmental variables of municipalities included in the higher-risk purely spatial clusters with those in the lower-risk clusters showed important differences between these two groups. All analyses resulted in significant p-values, with the exception of the variable percentage of urbanization (Table 1). The higher-risk areas showed higher temperatures, lower precipitation, and a lower percentage of natural vegetation.

The two significant clusters were identified using the space-time scanning statistics of the total cases. The higher-risk cluster, with an RR of 9.18 (Fig. 2B), occurred between 2014 and 2018, was identical to the purely spatial cluster that occupies the northwest region of the state and was localized mainly on the Araçatuba and São José do Rio Preto RHDs (Supplementary Material 1). The lower-risk cluster showed the same pattern presented in the purely spatial analysis; however, with a smaller size in the coastal region.

In the analysis of spatial variation in the temporal trends, two significant clusters were found in the total set of scorpion accidents. The values of their external and internal temporal trends are presented in Fig. 2C, highlighting the cluster located in the northwest region, also occupying the Araçatuba and São José do Rio Preto RHDs (Supplementary Material 1). It presented an internal annual increase of 34.3%, which was greater than the external increase (15.1%), with a high RR (4.13).

4. Discussion

This study sought to identify the spatial, temporal, and space-time clusters of scorpion accidents in SP from 2008 to 2018. Few studies have sought to identify the spatial and spatiotemporal clusters for the occurrence of accidents due to scorpions. Most studies refer to the geographical distribution of scorpion species of clinical importance and their respective incidences (Brites-Neto and Duarte, 2015; Shahi et al., 2016), failing to observe possible areas or regions that are more specific and vulnerable to the occurrence of these accidents (Silva et al., 2014, Barbosa et al., 2012). In this study, the scanning method was used to

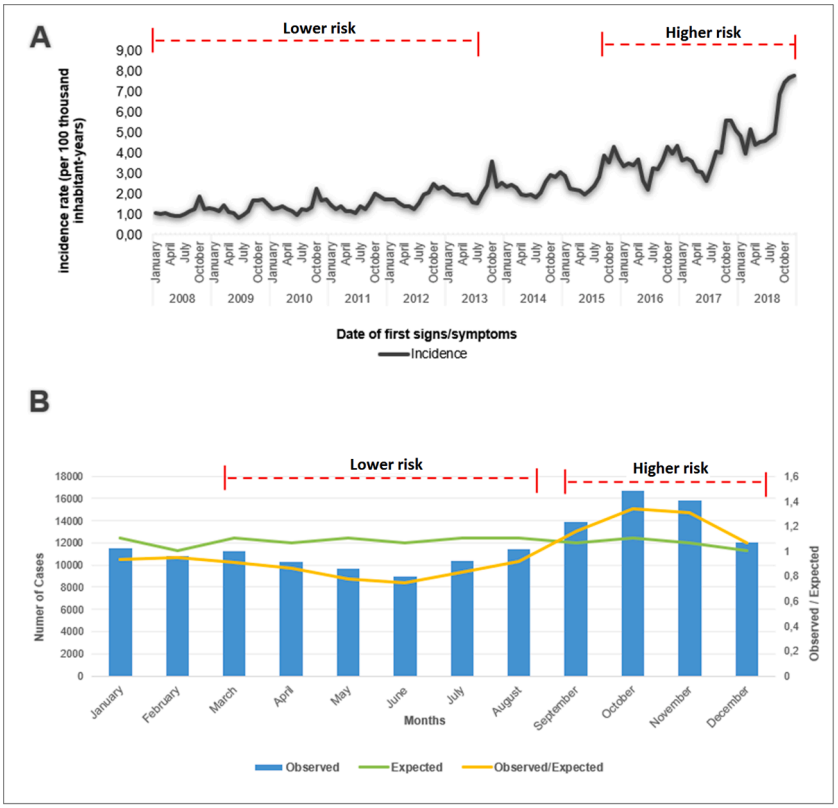

Fig. 1. Distribution of scorpion accidents in the state of São Paulo. (A) Purely temporal aspect of incidence rate from 2008 to 2018. (B) Seasonal analysis showing the low and high-risk months of occurrence.

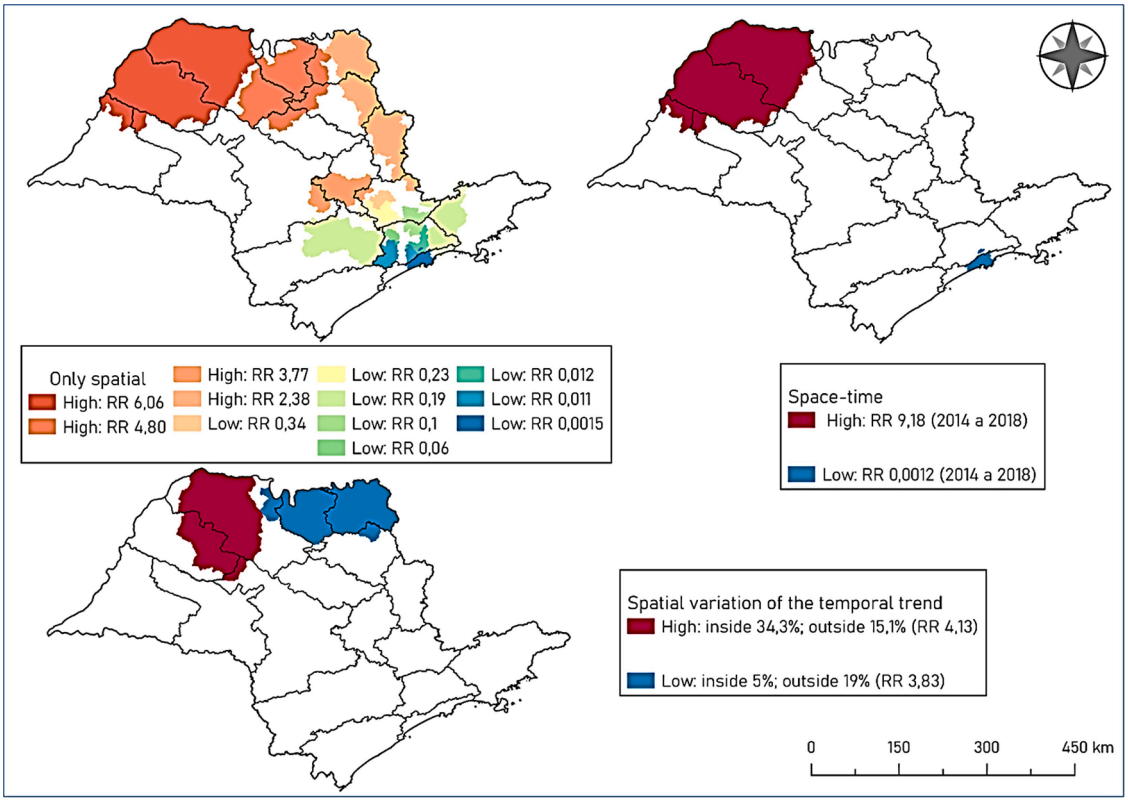

Fig. 2. Maps of clusters with high rates of scorpionism, according to the study area, Regional Health Department (RHD), cluster period and relative risk (RR). (A) Purely spatial analysis, (B) Spatio-time analysis and (C) Spatial variation of the temporal trend.

Table 1
Comparison of means between high and low risk clusters (*t*-test, two samples assuming equivalent variance). The number in parentheses indicates the standard deviation. *Indicates p value significant ($p < 0.0001$).

Variable	High-risk cluster	Low-risk cluster
Urbanization (%)	85.38 (10.24)	87.97 (17.08)
Natural vegetation (%)	9.91 (6.26)*	34.14 (22.70)*
Average day temperature (°C)	23.85 (1.01)*	21.50 (0.97)*
Average night temperature (°C)	17.92 (1.10)*	15.63 (1.13)*
Average precipitation (mm)	338.90 (42.09)*	421.74 (183.26)*
Thermal amplitude (C°)	12.71 (1.27)*	10.48 (1.82)*

target the identification of more vulnerable areas and time periods of the greatest risk to scorpionism. Our results showed that there was a great increase in the incidence of accidents (almost four times between 2008 and 2018), which was more pronounced between September 2015 and December 2018. This increase has been attributed to the improvement of the notification system and an increase in search for hospital care (Chippaux, 2015), but also represents the high affinity of scorpion species for anthropically altered environments, with consequent increases in contact with humans (Amado et al., 2021).

Specifically, in SP, the change of the main precursor species (*T. bahiensis*) to *T. serrulatus* throughout the territory may have had a great impact on scorpionism. The findings of Amado et al. (2021) confirmed the affinity of *T. serrulatus* for altered environments, as its modeled distribution is highly correlated with human population density in Brazil. Another factor that contributes to the increase in scorpion species in urban areas is parthenogenetic reproduction. As they are animals with easy adaptation, when scorpions find favorable conditions, they reproduce (Candido, 2008; Amado et al., 2021). The main control measure in Brazil is based on the removal/collection of scorpions. In addition, other preventive measures can be adopted, such as preserving the natural enemies of scorpions, especially nocturnal birds, eliminating food sources for scorpions such as cockroaches and spiders, keeping yards and gardens clean, not accumulating dry leaves and household waste (MS, 2019).

In relation to seasonality, we note that the most important period for scorpion accidents in SP was the spring season. Being a tropical region, the four seasons of the year are not well defined; however, spring marks the arrival of high temperatures, and rainfall becomes more intense and more frequent. Similar results were found in other Brazilian areas (Barbosa et al., 2012; Albuquerque et al., 2013) and other countries (Bahloul et al., 2010; Nejati et al., 2018; Firoozfar et al., 2019; Firooziyan et al., 2020) where scorpion accidents have been reported to be more frequent in the hotter and rainy periods of the year. On the other hand, some studies (Carmo et al., 2019) showed a uniformity of scorpionism occurrence over the months of the year, which could be explained by ideal temperatures, humidity, and abundant food throughout the year (Carmo et al., 2019).

We identified that the higher-risk areas were mainly concentrated in the northern and northwestern regions of the state throughout the analyzed period Paula et al. (2020). also showed these regions as hotspots of medical concern for scorpionism. All the higher-risk areas were consistent with higher temperatures, lower precipitation, and a lower percentage of natural vegetation, indicating a possible association of these factors with the occurrence of scorpion accidents. The results corroborate those of Moradiasl et al., 2019, who identified average temperature, annual humidity, and precipitation as environmental variables that affected the occurrence of scorpions in Iran. As temperatures increased and rainfall decreased, an increase in scorpion accidents was observed, which characterizes these environmental factors as ideal for more cases of such events. In their recent study in Iran, Rafinejad et al. (2020) considered climatic variations as important factors for the spread of scorpions in the country, as well as their accelerated generation and maturation. The description of environments more conducive for the presence of scorpions makes the localities with higher temperature and lower precipitation the ones that need more epidemiological attention due to the ideal conditions for the survival and proliferation of these scorpion species, which will consequently cause more cases of scorpionism in these areas.

The higher natural vegetation cover within the municipalities located in the lower-risk areas was a protective factor against scorpion accidents. Kotvitski and Barbola, (2013) also identified the presence of scorpion accidents away from the green areas. Natural vegetation is an important environmental factor because scorpions have predators in such areas Kotvitski and Barbola, (2013), decreasing the probability of their contact with humans. Although the percentage of urbanization has not been shown to be different between the lower-and higher-risk areas, the areas with less natural vegetation can be inferred to be more urbanized. The effects of urbanization on cities and deforestation, such as the lack of basic sanitation and geographic, social, and economic heterogeneity, can influence the appearance and adaptation of scorpions in urban environments (Zanella et al., 2018; Braga et al., 2021) McIntyre (1999). studied scorpions in Phoenix metropolitan area and found that land use influences the distribution of accidents. It is likely that scorpions respond to small-scale variations in land use. Other factors, such as vegetation type, most likely play crucial roles in scorpion abundance McIntyre (1999). also found that land use may interact with other factors, such as presence of palm trees and woodpiles (which may provide cover) and irrigation (which may contribute to a greater abundance of arthropod prey).

The cluster of spatial variation of the temporal trend located in the northwest region of the state deserves attention having presented an internal annual increase greater than the external and a high RR. These results show that this area, even though an important location for the occurrence of accidents with scorpions, may, in the future, have its epidemiological importance further increased, if the temporal growth trend is confirmed (Areias et al., 2015). Although the problem of scorpionism is present throughout SP, this area needs to be prioritized in terms of epidemiological surveillance, scorpion control, and health care. Lower-risk areas for scorpion accidents have milder temperatures, more rain and high natural vegetation cover. On the other hand, all higher-risk areas show a consistent pattern of high temperatures, low rainfall and low natural vegetation cover. Large-scale disturbances to the soil result from new construction and development could displace scorpions from their subterranean burrows, causing them to seek refuge in nearby homes (McIntyre, 1999). Future studies should address other factors that may be affecting the distribution of scorpionism, such as socioeconomic characteristics of each region.

We believe that the spatiotemporal methodological approaches that deal directly with epidemiological data can be great allies in helping researches tackle such issues, besides spatial prioritization and documentation of the reality of epidemiology of scorpionism in SP. It appears that scorpions will be increasingly adapted to urban environments, and thus, in addition to climate change scenarios, the number of accidents will increase. Therefore, the implementation of educational programs for the prevention and treatment of envenomation by scorpions offered to community and health agents, can be an effective measure of public policy to reduce the growing number of cases (Braga et al., 2020).

5. Conclusion

Between 2008 and 2018, there was a four-fold increase in the scorpion incidence in SP. Accidents occurred more frequently in spring, and the higher-risk clusters were found in the northern and northwestern regions of the state. The Araçatuba and Ribeirão Preto RHDs were characterized as the regions with the highest vulnerability to scorpion accidents and represented importance in all spatial applications. High temperatures, low precipitation, and poor natural vegetation are associated with higher risk areas. This study helped reveal priority areas, both for programmatic actions in the scope of scorpion accidents and to guide future studies.

Funding

Brazilian National Council for Scientific and Technological Development (CNPq) grant 130489/2020-4 (A.B.L.) and São Paulo Research Foundation (FAPESP) grant 2017/10297-1 (C.L.).

Supplementary Material

S1. State of São Paulo and its 645 municipalities and 17 Regional Health Departments (A); Localization of the state of São Paulo in Brazil and South America (B).

S2. Standardized incidence rates of scorpionism (100,000 inhabitant-years) for the 17 Regional Health Departments (RHDs) of the state of São Paulo, from 2008 to 2018.

CRediT authorship contribution statement

Alec Brian Lacerda: Formal analysis, Investigation, Writing – original draft. **Camila Lorenz:** Formal analysis, Investigation, Writing – original draft. **Thiago Salomão Azevedo:** Visualization, Investigation, Writing – review & editing. **Denise Maria Cândido:** Visualization, Investigation, Writing – review & editing. **Fan Hui Wen:** Visualization, Investigation, Writing – review & editing. **Luciano José Eloy:** Visualization, Investigation, Writing – review & editing. **Francisco Chiaravalloti-Neto:** Supervision, Investigation, Writing – review & editing.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abroug, F., Souheil, E., Ouanes, I., Dachraoui, F., Fekih-Hassen, M., Ouanes Besbes, L., 2015. Scorpion-related cardiomyopathy: clinical characteristics, pathophysiology, and treatment. Clin. Toxicol. 53 (6), 511–518.

Albuquerque, C.M.R.D., Santana, P.D.L., Amorim, M.L.P., Pires, S.C.V, 2013. Pediatric epidemiological aspects of scorpionism and report on fatal cases from Tityus stigmurus stings (Scorpiones: Buthidae) in State of Pernambuco, Brazil. Rev. Soc. Bras. Med. Trop. 46, 484–489.

Almeida, T.S.O., de Castro, M.C.A.B., Fook, S.M.L., Camêlo, E.L.S., Gomes, L.C.F., de Figueiredo, T.M.R.M., Pereira, V.R.A, 2020. The relationship between geographic space and the incidence of scorpion accidents in the context of social vulnerability. Rev. Electron. Acervo Saude 12 (12) e3950-e3950.

Amado, T.F., Moura, T.A., Riul, P., Lira, A.F.D.A., Badillo-Montaño, R., Martinez, P.A, 2021. Vulnerable areas to accidents with scorpions in Brazil. Trop. Med. Int. Health 26 (5), 591–601.

Araújo, M.V., et al., 2016. Epidemiological analysis and the spatial and temporal distributions of accidents caused by scorpion stings in the city of Americana, São Paulo, Brazil. BEPA 156 (13), 1–18.

Areias, C., Briz, T., Nunes, C., 2015. Pulmonary tuberculosis space–time clustering and spatial variation in temporal trends in Portugal, 2000–2010: an updated analysis. Epidemiol. Infect. 143 (15), 3211–3219. https://doi.org/10.1017/S0950268815001089.

Bahloul, M., Chabchoub, I., Chaari, A., Chtara, K., Kallel, H., Dammak, H., Bouaziz, M., 2010. Scorpion envenomation among children: clinical manifestations and outcome (analysis of 685 cases). Am. J. Trop. Med. Hyg. 83 (5), 1084.

Barbosa, A.D., Magalhães, D.F.D., Silva, J.A.D., Silva, M.X., Cardoso, M.D.F.E.C., Meneses, J.N.C., Cunha, M.D.C.M., 2012. Epidemiological study of scorpion stings in Belo Horizonte, Minas Gerais state, Brazil, 2005-2009. Cad. Saude Publica 28 (9), 1785–1789.

Braga, J.R.M., Souza, M.M.C.D., Melo, I.M.L.D.A., Faria, L.E.M., Jorge, R.J.B., 2021. Epidemiology of accidents involving venomous animals in the State of Ceará, Brazil (2007-2019). Rev. Soc. Bras. Med. Trop. 54.

Brites-Neto, J., Duarte, K.M, 2015. Modeling of spatial distribution for scorpions of medical importance in the São Paulo State, Brazil. Vet World 8 (7), 823–830.

Candido, D.M. 2008. Escorpiões: ocorrência das espécies de importância médica, acidentes no Estado de São Paulo, obtenção de veneno e manutenção em cativeiro.

Carmo, É.A., Nery, A.A., Nascimento, C.L., Casotti, C.A, 2019. Clinical and epidemiological aspects of scorpionism in the interior of the state of Bahia, Brazil: retrospective epidemiological study. Sao Paulo M J 137, 162–168.

Chippaux, J., 2015. Epidemiology of envenomations by terrestrial venomous animals in Brazil based on case reporting: from obvious facts to contingencies. J. Venom. Anim. Toxins 21, 13.

Cupo, P., 2015. Clinical update on scorpion envenoming. Rev. Soc. Bras. Med. Trop. 48, 642–649.

Dabo, A., Golou, G., Traoré, M.S., Diarra, N., Goyffon, M., Doumbo, O., 2011. Scorpion envenoming in the north of Mali (West Africa): epidemiological, clinical and therapeutic aspects. Toxicon 58 (2), 154–158.

Firoozfar, F., Saghafipour, A., Vatandoost, H., Bavani, M.M., Taherpour, M., Jesri, N., Yazdani, M., Arzamani, K., 2019. Faunistic composition and spatial distribution of scorpions in North Khorasan Province northeast of Iran. J. Arthropod. Borne Dis. 13 (4), 369–377.

Firoozyan, S., Sadaghianifar, A., Rafinejad, J., Vatandoost, H., Bavani, M.M, 2020. Epidemiological characteristics of scorpionism in West Azerbaijan Province, Northwest of Iran. J. Arthropod-Borne Dis. 14 (2), 193.

Furtado, A.A., Daniele-Silva, A., da Silva-Júnior, A.A., de Freitas Fernandes-Pedrosa, M., 2020. Biology, venom composition, and scorpionism induced by brazilian scorpion Tityus stigmurus (Thorell, 1876)(Scorpiones: Buthidae): a mini-review. Toxicon 185, 36–45.

Han, J., Zhu, Li., Kulldorff, M., Hostovich, S., Stinchcomb, D.G., Tatalovich, Z., Lewis, D. R., Feuer, E.J, 2016. Using Gini coefficient to determining optimal cluster reporting sizes for spatial scan statistics. Int. J. Health Geogr. 15, 27.

Kotvitski, B.M., Barbola, I.F., 2013. Aspectos espaciais do escorpionismo em Ponta Grossa, Paraná, Brasil. Cad. Saude Publica 29 (9), 1843–1858.

Kulldorff, M., 2021. SaTScanTM User Guide - for version 10.0. Available at. https://www.satscan.org/. Accessed on 1 Sep 2021.

McIntyre, N.E., 1999. Influences of urban land use on the frequency of scorpion stings in the Phoenix, Arizona, metropolitan area. Landscape Urban Plan 45 (1), 47–55.

Moradiasl, E., Adham, D., Solimanzadeh, H., Saghafipour, A., Eghbal, H., 2019. The impact of climatic factors on spatial distribution of scorpion stings in Ardabil Province, North-West of Iran; 2012 - 2017. Shiraz E-Med. J. 20 (2), e69333.

MS, 2019. Ministério da Saúde do Brasil. Manual de controle de escorpiões. Ministério da Saúde, Secretaria de Vigilância em Saúde. Ministério da Saúde, Departamento de Vigilância Epidemiológica – Brasília, p. 72, 2019.

Nejati, J., Saghafipour, A., Rafinejad, J., Mozaffari, E., Keyhani, A., Abolhasani, A., Kareshk, A.T, 2018. Scorpion composition and scorpionism in a high-risk area, the southwest of Iran. Electron Physician 10 (7), 7138.

Oliveira, A.F.G., 2008. Testes estatísticos para comparação de médias. Rev. Ele Nutr. 5 (6), 777–788.

Paula, L.G.G., Moreira, G.C., Castiglioni, L., Mendes, C.A.C., 2020. Levantamento clínico-epidemiológico de acidentes escorpiônicos na região de São José do Rio Preto, São Paulo, Brasil. Arq. Ciências Saude 27 (1), 32–36.

QGIS Development Team, 2021. QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org.

Rafinejad, J., Shahi, M., Navidpour, S., Jahanifard, E., Hanafi-Bojd, A.A., 2020. Effect of climate change on spatial distribution of scorpions of significant public health importance in Iran. Asian Pac. J. Trop. Med. 13 (11), 503.

Santos, A.M.L., Magalhães, P.K.A., Jesus, L.C.C., Araújo, E.N., Araújo, L.M., Correia, M. S., Matos-Rocha, T.J., 2021. Epidemiological aspects of scorpionic accidents in a municipality in Brazil's northeastern. Braz. J. Biol. 82.

Santos, M.S., Silva, C.G., Neto, B.S., Júnior, C.R.G., Lopes, V.H., Júnior, A.G.T., Lima, M. A, 2016. Clinical and epidemiological aspects of scorpionism in the world: a systematic review. Wild Environ. Med. 27 (4), 504–518.

Shahi, M., Moosavy, S.H., Hanafi-Bojd, A.A., Navidpour, S., Zare, S., Madani, A., Rafinejad, J., 2016. Spatial distribution of scorpion sting in a high-risk area of Southern Iran. J. Med. Entomol. 53 (5), 1198–1204.

Silva, J.F.A., Catão, R.C., Guimarães, R.B., 2014. Análise da distribuição espacial das notificações de escorpiões em Presidente Prudentes - SP, 2013. In: V Congresso Internacional De Geografia da Saúde.

Sociedade Brasileira De Medicina Tropical, 2019. Acidentes com Escorpiões: Aumento Expressivo Preocupa Autoridades e População. Available at: https://www.sbmt.org.br/portal/accidents-with-scorpions-significant-increase-worries-authorities-and-population/Accessed, 10 Oct 2021.

Souza Jr., C.M., Shimbo, J.Z., Rosa, M.R., Parente, L.I., Alencar, A.A., Azevedo, T, 2022. Reconstructing three decades of land use and land cover changes in Brazilian biomes with landsat archive and earth engine. Remote Sens. 12, 2735.

TRMM - Tropical Rainfall Measuring Mission, 2011. TRMM Microwave Imager Precipitation Profile L3 1 Month 0.5 Degree x 0.5 Degree V7. Goddard Earth Sciences Data and Information Services Center (GES DISC), Greenbelt, MD. Available at. https://disc.gsfc.nasa.gov/datacollection/TRMM_3A12_7.html. Acessed 6 January 2022.

Torrez, P.P.Q., Dourado, F.S., Bertani, R., Cupo, P., França, F.O.D.S., 2019. Scorpionism in Brazil: exponential growth of accidents and deaths from scorpion stings. Rev. Soc. Bras. Med. Trop. 52 (2), 34–40.

Zanella, D.P., Valadão, A.F., Aredes, C.A.M., Campos, G.C.T., Cordeiro, N.D.B., Spencer, P.J., 2018. Escorpionismo no Vale do Aço, Minas Gerais. Braz. J. Surg. Clin. Res. 23 (1), 60–66.