Revista ARACÊ
ISSN: 2358-2472

CAPTURE METHODS AND BIOLOGICAL CLASSIFICATION OF SCORPIONS: TRENDS IN RESEARCH PUBLISHED IN BRAZIL (2013-2023)

https://doi.org/10.56238/arev7n3-112

Date of submission: 13/02/2025 **Date of publication:** 13/03/2025

Randyson da Silva Pinheiro[1], Bruno Sousa Costa[2], Marcos Vinicius Costa Santos[3], Marcelo Cardoso da Silva Ventura[4], Roseli Farias Melo de Barros[5] and Paulo Roberto Ramalho Silva[6]

ABSTRACT

The global and Brazilian context of research involving scorpions faces challenges in the identification of samples at different taxonomic levels. Predominantly, studies in different areas require the collection and identification of scorpions to achieve these objectives. In this scoping review, we aim to identify the most common methods of situ collection and biological classification of scorpions in scientific articles published between 2013 and 2023, in addition to providing an overview of the main lines of research involving the management of these animals. To this end, a comprehensive search was conducted on the Web of Science, Science Direct, and PubMed databases, subjecting the results to a thorough four-step eligibility analysis. The results revealed that the amount of research involving the collection and/or identification of scorpions significantly increased from 2018 to 2022, in addition to the fact that the leading state in the production of these studies was Pernambuco. With respect to the collection method, the studies predominantly used an active search with ultraviolet light, in addition to morphological identification being dominant in these products. With respect to research strands, studies focused predominantly on the ecology and ethology of scorpions. The survey revealed that the studies of these animals remain in a traditional pattern, with little expressiveness of methods such as integrative taxonomy. This review can contribute significantly to the training of beginning researchers, especially those focused on issues related to scorpionism.

Keywords: Arachnology. Zoological research. Scorpiones. Taxonomy of Scorpions.

[1] Graduate in Biological Sciences
Postgraduate Program in Development and Environment – Federal University of Piauí
E-mail: randysonpinheiro22@gmail.com
[2] Graduate in Biological Sciences
Postgraduate Program in Development and Environment – Federal University of Piauí
[3] Undergraduate Student in Biological Sciences
Molecular Biology and Epidemiology Laboratory – Federal Institute of Piauí
[4] Master in Biodiversity, Environment, and Health
Molecular Biology and Epidemiology Laboratory – Federal Institute of Piauí
[5] PhD in Botany
Postgraduate Program in Development and Environment and Department of Biology/Nature Sciences Center – Federal University of Piauí
[6] PhD in Animal Biology
Postgraduate Program in Development and Environment and Department of Plant Science/Agrarian Sciences Center – Federal University of Piauí

Revista ARACÊ
ISSN: 2358-2472

INTRODUCTION

Since the end of the eighteenth century, research on scorpions has focused primarily on the taxonomic classification, anatomy and distribution of species (Lourenço, 2016). In the last century, driven mainly by public health problems related to scorpionism, the area of study began to diversify its focus, with ecological, epidemiological and biochemical studies involving these animals.

Knowledge about the biodiversity of scorpions in any territory is essential for decision-making regarding the prevention of accidents and complications arising from this faunal group, which is becoming an important public health strategy. In addition, these animals and their numbers can serve as biological indicators of environmental degradation both in urban areas, since some species are synanthropic, and in areas that are still natural, considering other groups with greater specificity in relation to habitat (Lourenço & Cuellar, 1995; Colombo & Alencar, 2014; Lira et al., 2020). Regardless of the objective, the vast majority of experimental studies involving scorpions require the capture of samples, and practically all involve identification.

The biological classification of the order Scorpiones is a considerable challenge for researchers in general, especially those who focus on aspects involving humans and scorpionism1. The confusing classification used in most studies can lead to harmful conclusions for the area itself, such as the growing number of species of medical importance in the world and the possible implications of this (Lourenço, 2020). With respect to the capture of samples, many studies basically benefit from two methodologies, often disregarding the subjectivity of each environment where the research is carried out, an approach that can significantly influence the results, especially in ecological studies (Dehghani et al., 2019).

In Brazil, the last decade has been marked by the large-scale growth of accidents involving scorpions in all regions, increasing scientific production in the same area. To provide useful information for the practice of studying these arthropods and in view of the lack of similar literature, in this scoping review, we aim to identify the methods of in situ collection and biological classification of scorpions most common in scientific articles published between 2013 and 2023 in the selected databases, in addition to building an overview of the main lines of research involving the management of these animals.

Revista ARACÊ
ISSN: 2358-2472

METHODOLOGY

The Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) was used as a parameter for the design of the present study. The Web of Science, Science Direct and PubMed database searches were carried out from January to May 2024, where the following terms were used: "brazil"; "catch"; "collect"; "identification"; "classification"; "scorpion" and "Scorpiones", as well as their verbal inflections, variations of similar meaning and necessary Boolean operators. The searches were originally conducted in English, without excluding papers that were presented in full in a different language.

All stages of identification, screening, eligibility and complete reading were carried out by two authors independently, with decision divergences resolved by complete consensus (4 articles) or by the tie-breaking vote of a third author (1). The results of the databases were initially gathered in an Excel table, and the exclusion of duplicates between the databases was performed in two layers, the first by Endnote, and the second by manual checking in Excel.

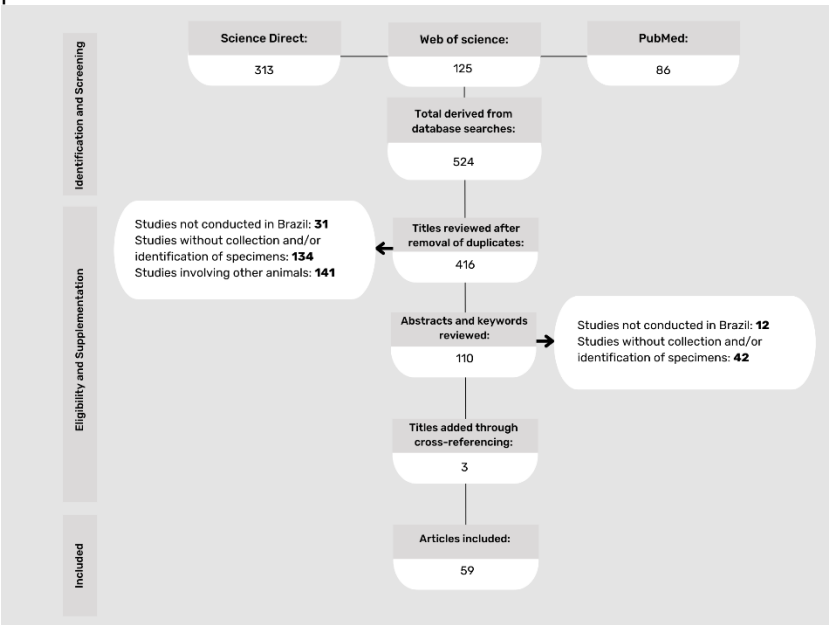
Additional literature was integrated into the review according to recurring authors in the references of the included articles, and one of the authors on the Research Rabbit platform was actively searched. The screening and eligibility of the studies were carried out in two stages, namely, reading the title and abstract and complete reading, on the basis of the following exclusion criteria: 1) book chapters, event publications, or articles in press; 2) carried out outside Brazil; and 3) did not collect or identify scorpions. Finally, the following information was extracted from the articles eligible for inclusion in the review: year of publication, state of Brazil where the study was conducted, journal of publication, research area of the study, research object, type of collection, identification method, number of species, and number of specimens included.

RESULTS

The initial search for papers returned a significant number of publications, which, after being submitted to the screening stages, were reduced to 59 scientific articles eligible for adoption in the present study (Figure 1).

Revista ARACÊ
ISSN: 2358-2472

Figure 1. Results of the different stages of the search and screening of articles related to the collection or identification of scorpions in Brazil.



Source: Authors, 2024

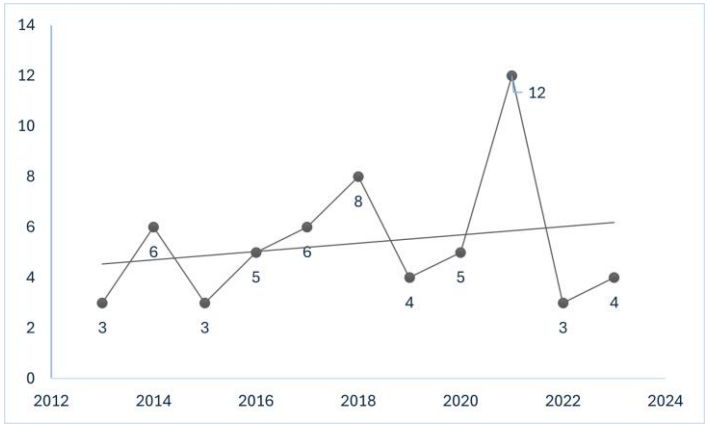
Most of the studies not included dealt with research aimed at the classification and bioprospecting of chemical compounds present in the venom of animals, with the process of collection and identification previously carried out by institutions that donated the biological material for the research. Others, discarded during the eligibility stage, did not have sufficient information about the method used to capture and classify the animals. Even with the use of a term that specifies the study area as Brazil and restricts the searches to the order Scorpiones, works outside this scope were also evaluated and discarded during the screening.

The scientific results indicate a growth trend in the study area (Figure 2), with emphasis on the years 2018 (8) and 2021 (12), which presented the highest amount of production in the period. For the most discussed subjects, animal behavior and the analysis of the influence of environmental factors on scorpion diversity are highlighted in production.

The studies analyzed covered several aspects of knowledge, with ecology being the most representative (n = 20), with emphasis on the description of microhabitats and the effects of environmental variations on scorpion assemblages. The second strand of studies was ethology (n = 11), with investigations focused mainly on reproductive, defensive and predatory behavior. Third, Biotechnology (n = 10) stands out in terms of the characterization of venom and identification of biomolecules, and fourth, Taxonomy (n = 7), with a predominance of descriptions of new species.

Revista ARACÊ
ISSN: 2358-2472

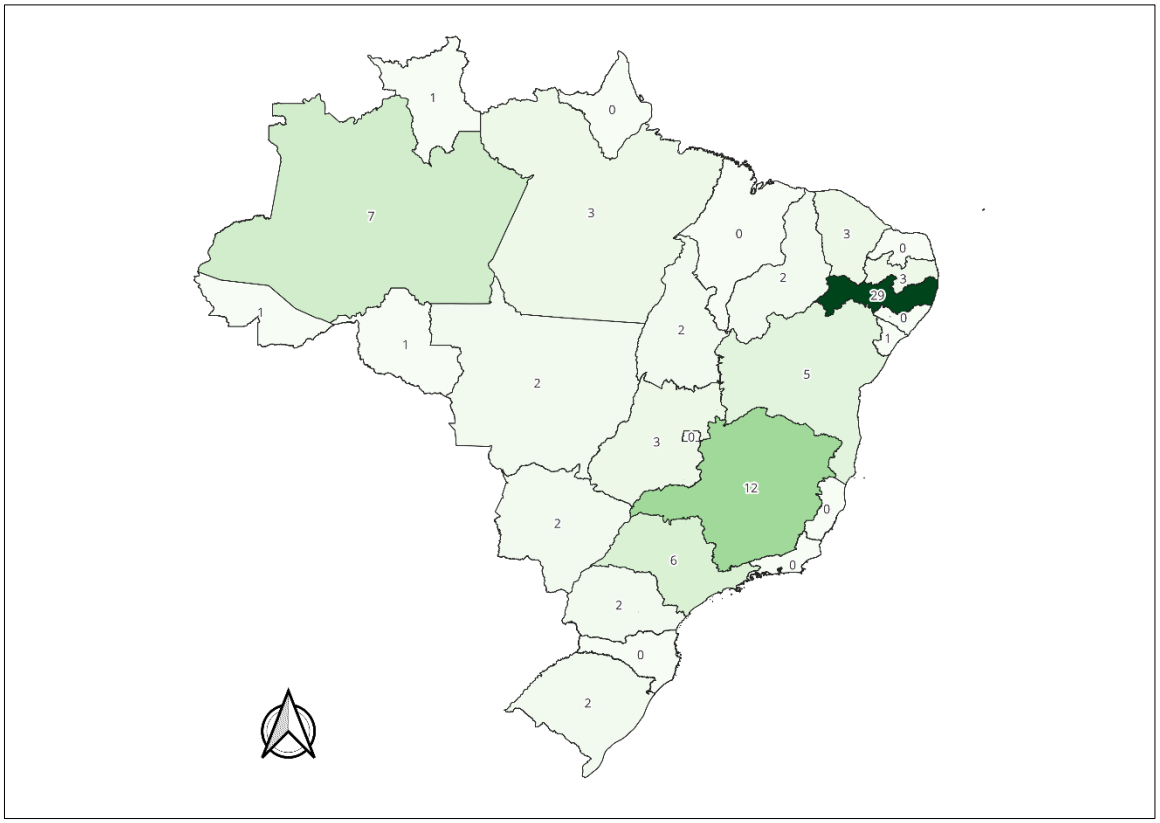
Figure 2. Production per year among the articles that address the collection and/or identification of scorpions in Brazil from 2013–2023.



Source: Authors, 2024

Finally, the literature studied was mainly concentrated in Northeast Brazil (Figure 3), with an emphasis on the state of Pernambuco (29). It was also possible to verify a significant number of studies (8) carried out in partnership between researchers from different states, focusing mainly on studies of the diversity of biochemical and/or molecular patterns.

Figure 3. Numbers of articles concerning the collection and/or identification of scorpions by the Brazilian Federation from 2013–2023



Source: Authors, 2024

Revista ARACÊ
ISSN: 2358-2472

The most used in situ collection method in these studies was an active search with the use of ultraviolet lighting (22); in addition, capture by means of pitfall traps was mentioned in two articles. Identification through the observation of morphological characteristics and fitting of dichotomous keys was the most used taxonomic classification technique among the studies (37), and only one study used integrative classification, also considering molecular analysis for the definition of biological groups. Our results are shown in Table 1.

Table 1. Information extracted from studies dealing with the collection and/or identification of scorpions selected for review (2013--2023)

Authorship	Periodic	State	Slope	Object of study	Type of collection	Method of identification	Quant. species	Quant. of specimens
Lourenço et al., 2013	Anais da acad. Brasileira de Ciências	BA, MG	Taxonomy	New species	Not informed	Morphological	3	8
Mattos et al., 2013	Chromosome Research	BA, SP, TO, PI, PR, MG, CE	Cytogenetics	Chromosomal structure	Not informed	Morphological	11	78
Schwartz et al., 2013	Peptides	I'm	Biotechnology	Peptide prospecting	Not informed	Not informed	1	Not informed
Lira e Albuquerque, 2014	Check List	PE	Ecology	Characterization of the scorpion assemblage	Active - UV	Morphological	5	1.125
Lira e Sousa, 2014	Revista Ibérica de Aracnologia	PE	Ecology	Scorpion microhabitat	Active - UV	Morphological	3	23
Ott e Ott, 2014	Iheringia	RS	Ecology	Vegetation-dependent population variation	Passive-Fall	Morphological	1	165
Santos et al., 2014	Zookeys	BA	Taxonomy	Morphological description	Not informed	Morphological	3	2.264
Carmo et al., 2014	Toxicon	MG	Biotechnology	Protease profile of *Tityus serrulatus* Lutz & Mello, 1922	Not informed	Not informed	1	500
Horta et al., 2014	Plos One	MG	Cytogenetics	Intraspecific chromosomal variability	Not informed	Not informed	1	Not informed
Martins et al., 2014	Mitochondrial DNA	MG	Biotechnology	Mitochondrial genome of *Tityus serrulatus* Lutz & Mello, 1922	Not informed	Morphological	1	1
Mattoni et	Plos One	MT,	Ethology	Autotomy in	Active-	Not informed	10	150

Revista ARACÊ
ISSN: 2358-2472

al., 2015		MS, MG, SP, AM		scorpions	UV, Rolling			
Souza et al., 2016	Acta Scientiarum	PE	Ontogenetic	Ontogeny of *Tityus stigmurus* (Thorell, 1876)	Not informed	Not informed	1	Not informed
Santos et al., 2016	Chemico-biological interactions	RS	Toxicology	Poisoning of *Bothriurus bonariensis* (C. L. Koch, 1842)	Not informed	Not informed	1	Not informed
Albuquerque e Lira, 2016	Comptes Rendus Biologies	PE	Ecology	Ontogeny of *Tityus pusillus* Pocock, 1893	Not informed	Morphological	1	16
Lira et al., 2016	J. of Arachnology	PE	Morphology/Ecology	Leucism in *Tityus pusillus* Pocock, 1893	Not informed	Morphological	1	1
Costa et al., 2016	Revista da Soc. Brasileira de M. Tropical	AM	Epidemiology	Scorpionism in Amazonas	Not informed	Morphological	Not informed	Not informed
Lira et al., 2017a	Arachnida Aracnologica Italiana	PB	Ecology	Assemblage of scorpions in a Protected Area	UV-Active	Morphological	4	272
Lourenço, 2017	Zookeys	PA	Taxonomy	New species	Not informed	Morphological	1	Not informed
Chantall-Rocha e Japyassú, 2017	Behavioural Processes	SE, BA, MG	Ethology	Reproductive behavior	Active-UV, Rock Roll	Morphological	1	65
Lira et al., 2017b	Studies on neotrop. fauna and environment	PE	Ecology	Habitat particularities	Active-UV	Morphological	5	353
Silva et al., 2017	Toxicon	AM	Biotechnology	Pharmacological effect of the venom	Not Informed	Not Informed	1	Not informed
Lira et al., 2017c	Acta ethologica	PE	Ethology	Scorpion threat level	Not informed	Not informed	1	60
Bertani et al., 2018	Bioinvasions records	SP	Taxonomy	Occurrence and establishment of invasive species	Not informed	Morphological	1	180
Silva et al., 2018	Zoology	PE	Ethology/Ecology	Behavior and edge effect on two species of scorpion	Active-UV	Morphological	2	1.497
Lira et al., 2018a	Canadian J. of Zoology	PE	Ethology	Behavior of *T. pusillus* Pocock, 1893 in different Neotropical Brazilian forests	Active-UV	Morphological	12	2.681

Revista ARACÊ
ISSN: 2358-2472

Mattos et al., 2018	Plos One	AM, CE, GO, MG, MS, PI, PR, RR, PE	Cytogenetics	Molecular rearrangement of the subgenus *Archaeotityus*	Not informed	Morphological	6	137
Dias et al., 2018	J. of Proteomics	AM	Biotechnology	New peptide from the venom of *Tityus obscurus* (Gervais, 1843)	Not informed	Not informed	1	Not informed
Santos et al., 2018	European j. of entomology	PE	Ecology	Habitat particularities	Active-UV	Morphological	2	501
Lira et al., 2018b	Invertebrate biology	PE	Ethology	Sexual dimorphism and reproductive behavior of *T. pusillus* Pocock, 1893	Not informed	Morphological	1	634
Batista et al., 2018	Toxicon	AM	Biotechnology	Characterization of the venom of *T. metuendus* Pocock, 1897	Not informed	Morphological	1	Not informed
Pordeus et al., 2019	Canadian J. of Zoology	PE	Ethology	Behavior of *T. pusillus* Pocock, 1893	Not informed	Not informed	1	100
Silva et al., 2019	Acta ethologica	PE	Ethology	Predatory behavior of *Jaguajir rochae* (Borelli, 1910)	Not informed	Not informed	1	60
Lira et al., 2019a	Acta Oecologica	PE	Ethology	Behavioral variation in the face of environmental variations	Active-UV	Morphological	12	2.653
Lira et al., 2019b	International J. of Tropical Insect Science	PB, PE	Ecology	Influence of land use on the assembly	Active-UV	Morphological	9	461
Foerster et al., 2020	Neotrop. Biology and Conservation	PE	Ecology	Influence of land use on the assembly	Active-UV	Morphological	6	269
Lira et al., 2020a	J. of Ethology	PE	Ethology	Defensive behavior of *T. pusillus* Pocock, 1893	Not informed	Not informed	1	248
Yamazaki et al., 2020	Revista Colombiana de Entomología	MG	Ecology	Arthropods associated with *Callisthene fasciculata*	Canopy fogging	Not informed	1	3

Revista ARACÊ
ISSN: 2358-2472

				(Vochysiaceae)				
Lira et al., 2020b	Studies on neotrop. fauna and environment	PE	Ecology	Seasonal variation of foraging pattern	Active-UV	Morphological	7	96
Borges et al., 2020	Acta Tropica	PA, SP	Biotechnology	Diversity of venom composition in *Tityus* Koch, 1836	Not informed	Not informed	15	Not informed
Lira et al., 2021a	Acta amazônica	AC	Ecology	State species checklist	Not informed	Morphological	7	31
Brite-Neto et al., 2021	J. of Invertebrate Pathology	SP	Biotechnology	Anti-scorpion activity of fungal isolates	Active-UV	Morphological	1	1500
Albuquerque e Lira, 2021	The J. of Arachnology	PE	Ethology	Defense behavior *T. pusillus* Pocock, 1893	Not informed	Not informed	1	54
Braga-Pereira e Santos, 2021	The J. of Arachnology	MG	Ethology	Reproductive behavior of *Tityus serrulatus* Lutz & Mello, 1922	Active-UV, Rolling	Morphological	1	174
Lira et al., 2021b	Zoology	PE	Ecology	Morphological variation according to vegetation in the assemblage	Active-UV	Morphological	11	368
Lira et al., 2021c	The J. of Arachnology	PE	Ecology	Morphological variation according to vegetation *Tityus pusillus* Pocock, 1893	Active-UV	Morphological	1	353
Magalhães et al., 2021	J. of Proteomics	GO	Biotechnology	Venom of *Rhopalurus agamemnon* (Koch, 1839)	Not informed	Not informed	1	Not informed
Lira et al., 2021d	J. of Arid Environments	PE	Ecology	Influence of habitat heterogeneity on assemblages	Active-UV	Not informed	10	782
Lira et al., 2021e	International J. of Tropical Insect Science	PE	Ecology	Influence of the edge effect on assemblies	Fall trap	Morphological	5	864
Kalapothakis et al., 2021	Toxicon	MG	Biotechnology	New peptides in the venom of *Tityus serrulatus* Lutz & Mello, 1922	Not informed	Not informed	1	40
Lira et al., 2022	J. of Insect Conservation	PE	Ecology	Influence of anthropogenic disturbance on the assembly	UV-Active	Morphological	13	3.781

Revista ARACÊ
ISSN: 2358-2472

Lourenço et al., 2021	Zootaxa	GO	Taxonomy	New species by *Ananteris* Thorell, 1891	Not informed	Morphological	1	Not informed
Pessoa et al., 2022	Neotropical Biodiversity	PE	Ecology	Behavior of *Ananteris mauryi* Lourenço, 1982 at risk of predation	Active-UV	Not informed	2	380
Lima et al., 2022	Acta Scientiarum	PE	Ecology	Effect of photoperiod on biomass gain in *Jaguajir rochae* (Borelli, 1910)	Not informed	Not informed	1	71
Cunha et al., 2022	Acta Ethologica	PE	Ecology/Ethology	Influence of habitat on predation pattern	Active-UV	Morphological	4	30
Lima et al., 2023	Animal Genetics	AM, RO, MG, BA, MT, SP	Cytogenetics	Cytogenetic description of Buthidae and Chactidae	Not informed	Morphological	8	40
Alberto et al., 2023	Revista bras. de Paleontologia	EC	Taxonomy	New fossil species	Fossil	Morphological	1	1
Silva et al., 2023	Mutation Research	PE, PB	Toxicological genetics	Genotoxic effects of pollution in *Tityus pusillus* Pocock, 1893	Active-UV	Not informed	1	30
Pardal et al., 2023	Acta Amazonica	PA	Population genetics	Effect of genetic diversity on the clinical outcome of scorpionism	Not informed	Morphological	2	10

Source: Authors, 2024

DISCUSSION

Scoping reviews aim to compile the literature and highlight trends in a particular area, method, or specific topic on the basis of a descriptive analysis of materials extracted from selected databases. In the present study, we focus on exploring the trends and practices of research involving the collection and/or identification of scorpions in various themes within the area, with the objective of providing support to researchers who are new to the study of the order Scorpiones. The synanthropic behavior, evidenced in the last three decades in the country by the increase in the number of accidents with humans, the pharmacological potential explored by several research groups and the study of the

Revista ARACÊ
ISSN: 2358-2472

behavior and adaptation of these animals are some of the main motivations for a significant increase in scientific production in the area.

The biochemistry of venoms and the identification of their compounds were recurrent themes in the selected articles, whose studies have the potential to contribute to the development of health-related areas, considering the secondary use of some compounds extracted from the venoms of these arachnids. However, it is important to note that there is still not much specific work aimed at identifying scorpions themselves. Research in this field can provide valuable contributions to the understanding and application of these poisons in human health.

Among the articles that included identification and collection as part of the methodology, the Brazilian state of Pernambuco stood out for the number of studies carried out. Notably, these studies focused on the analysis of scorpion biodiversity via a survey of information related to the habitat and microhabitat of the species, mainly in forest regions, as well as on the behavioral analysis of these arachnids in natural or artificial spaces, especially those related to reproductive issues.

Our results indicated that the vast majority of studies focused on the elucidation of ecological issues involving scorpions, such as studies aimed at gathering information about the habitat of some kind, the comparison of the diversity or behavior of animals in different environments, and the analysis of reproductive behavior. We can associate the results with the mandatory integration of animal collection in studies *in situ*, ensuring the observation of aspects beyond natural behavior, such as morphological measurements and patterns. In addition, some studies have analyzed the behavior of animals in artificial environments, allowing observation for long periods and greater accuracy of the data collected.

Our results revealed that the collection of animals in situ has been carried out predominantly through active search via ultraviolet (UV) light, with the methods of pitfall traps and rock rolling being mentioned in significantly smaller numbers. Method integration occurred in three studies, with a combination of active and passive methods, regardless of the combination of methods. Importantly, the active search method with ultraviolet light does indeed provide more satisfactory sampling than the other methods do but requires greater human capital and presents a relatively higher risk, considering the possibility of unwanted encounters with other nonfluorescent animals under UV light.

The record of new species has also been the subject of focus in several studies. Considering the increasing number of studies on the order Scorpiones in recent decades,

Revista ARACÊ
ISSN: 2358-2472

new species are expected to be cataloged, and considering Brazil as being highly diverse, a different pattern is not expected. However, Lourenço (2020) noted that this trend can be worrying since many classifications (or reclassifications) do not follow important principles for the proposition of new species. It is understood as essential for the notification of new taxa to consider ecological aspects, the number of specimens evaluated or other information that indicates speciation, avoiding early identification on the basis of few morphological differentiations.

The predominance of studies in the areas of ecology and ethology may be related to their relevance to understanding the population dynamics, ecological interactions and behavioral strategies of scorpions, which are essential aspects for the conservation and management of these species. In addition, these strands represent areas of knowledge that are still poorly explored in Brazil, which justifies the growing interest in such investigations. The significant amount of research in these fields also reflects the work of a consolidated research group in Pernambuco, which has been largely dedicated to the study of the ecology and behavior of arachnids. This group has developed detailed investigations into the composition of assemblages, the influence of environmental factors and the behavioral patterns of scorpions in different habitats, contributing significantly to the advancement of knowledge about these organisms.

Among the studies selected in our study that mention the form of identification of specimens, morphological classification stands out significantly, and only one study pointed to the use of integrative taxonomy as a classificatory method. The specialized literature of Lourenço (2002), which addresses the Brazilian scorpion fauna on different fronts, was the most cited by the authors as a basis for identification, even though in some cases, species reported in these works had their morphology more explored in later works. Conservatism regarding the diversification of basic literature seems to be predominant within the collaboration networks that study scorpions.

The debate over taxonomic classification techniques has permeated academia since the early days of the study of life, and the most popular trend among zoologists changed several times during this period. While traditional morphological analysis remains dominant, groups of researchers have emerged with the defense of molecular biology as the center of biological classifications, including the adoption of a universal barcode (Daglio; Dawson, 2019). In this context, the integrative taxonomy approach gains strength, which seeks the best of both areas to define biological groups, in addition to including other factors such as

Revista ARACÊ
ISSN: 2358-2472

behavior or ecological individualities. Only one of the studies included in this review adopted molecular classification (Martins et al., 2015), and all the other studies used morphological methods.

FINAL CONSIDERATIONS

The integration of different disciplines, concepts and practitioners has become increasingly necessary for the elucidation of emerging problems around the world, especially in tropical countries. Scientific production is increasingly accessible, enabling communication between researchers to achieve greater objectives, such as goals of the 2030 agenda or combating neglected tropical diseases.

We aim to demonstrate, in a succinct way, the most common methods in research with scorpions, an animal group that has been increasingly highlighted among invertebrates, either for its biological particularities or for its potential danger to humans. We hope that the contributions listed here will serve as a conceptual basis for the construction of scientific plans and projects in different areas of scientific research or public health actions aimed at the population control of scorpions. We highlight the nonintegration of articles published outside the scope of the selected databases as a limitation of the study.

ACKNOWLEDGEMENTS

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001

Revista ARACÊ
ISSN: 2358-2472

REFERENCES

1. ALBERTO GM, BEZERRA FI, GIUPPONI APL, MENDES M. A new specimen of whip scorpion (Arachnida; Thelyphonida) from the Crato Formation, Lower Cretaceous of Brazil. **Revista Brasileira de Paleontologia**, v. 26, n. 3, p. 147–155, 2023. https://doi.org/10.4072/rbp.2023.3.01.

2. ALBUQUERQUE CMR, LIRA AFA. Insights into reproductive strategies of Tityus (Archaeotityus) pusillus Pocock, 1893 (Scorpiones, Buthidae). **Comptes Rendus Biologies**, v. 339, n. 5-6, p. 179–184, 2016. https://doi.org/10.1016/j.crvi.2016.03.003.

3. ALBUQUERQUE KBC, LIRA AFA. Sex-based defensive behavior influenced by threat level in the scorpion Tityus pusillus (Scorpiones: Buthidae). **The Journal of Arachnology**, v. 49, n. 3, 2021. https://doi.org/10.1636/JoA-S-20-074.

4. BATISTA CVF, MARTINS JG, RESTANO-CASSULINI R, CORONAS FIV, ZAMUDIO FZ, PROCÓPIO R, POSSANI LD. Venom characterization of the Amazonian scorpion Tityus metuendus. Toxicon, v. 143, p. 51–58, 2018. https://doi.org/10.1016/j.toxicon.2018.01.006.

5. BERTANI R, BONINI RK, TODA MM, ISA LS, FIGUEIREDO JVA, SANTOS MR, FERRAZ SC Alien scorpions in the Municipality of São Paulo, Brazil: evidence of successful establishment of Tityus stigmurus (Thorell, 1876) and first records of Broteochactas parvulus Pocock, 1897, and Jaguajir rochae (Borelli, 1910). **Bioinvasions Rec.** v. 7, n. 1, p. 89-94, 2018. https://repositorio.butantan.gov.br/handle/butantan/2406?locale=pt_BR.

6. BORGES A, LOMONTE B, ANGULO Y, PATIÑO HA, PASCALE JM, OTERO R, MIRANDA RJ, SOUSA L, GRAHAM MR, GÓMEZ A. Venom diversity in the Neotropical scorpion genus Tityus: implications for antivenom design emerging from molecular and immunochemical analyses across endemic areas of scorpionism. **Acta Tropica**, v. 204, p. 105346, 2020. https://doi.org/10.1016/j.actatropica.2020.105346.

7. BRAGA-PEREIRA GF, SANTOS AJ. Asexual reproduction in a sexual population of the Brazilian yellow scorpion (Tityus serrulatus, Buthidae) as evidence of facultative parthenogenesis. **The Journal of Arachnology**, v. 49, n. 2, p. 1-12. 2021. https://doi.org/10.1636/JoA-S-20-001.

8. BRITES-NETO J, MAIMONE NM, PIEDADE SMS, ANDRINO FG, ANDRADE PAM, BARONI FA, GOMES LH, LIRA SP. Scorpionicidal activity of secondary metabolites from Paecilomyces sp. CMAA1686 against Tityus serrulatus. **Journal of Invertebrate Pathology**, v. 179, p. 107541, 2021. https://doi.org/10.1016/j.jip.2021.107541.

9. CARMO AO, OLIVEIRA-MENDES BBR, HORTA CCR, MAGALHÃES BF, DANTAS AE, CHAVES LMM, CHÁVEZ-OLÓRTEGUI C, KALAPOTHAKIS E. Molecular and functional characterization of metalloserrulases, new metalloproteases from the Tityus serrulatus venom gland. **Toxicon**. v. 90, p. 45–55, 2014. https://doi.org/10.1016/j.toxicon.2014.07.014.

Revista ARACÊ
ISSN: 2358-2472

10. CHANTALL-ROCHA S, JAPYASSÚ HF. Diffuse resistance courtship in the scorpion Rhopalurus rochai (Scorpiones: Buthidae). **Behavioural processes**, v. 135, p. 45–55, 2017. https://doi.org/10.1016/j.beproc.2016.11.017.

11. COLOMBO WD, ALENCAR ICC. Etograma do escorpião amarelo *Tityus serrulatus* Lutz & Mello 1922 (*Scorpiones: Buthidae*), em cativeiro**. Bioscience Journal**, v. 30, n. 2, p. 576-581, 2014. https://seer.ufu.br/index.php/biosciencejournal/article/view/18217

12. COSTA CLSO, FÉ NF, SAMPAIO I, TADEI WP. A profile of scorpionism, including the species of scorpions involved, in the State of Amazonas, Brazil. **Rev Da Soc Brasil De Medicina Tropical**, v. 49, n. 3, 376–379, 2016. https://doi.org/10.1590/0037-8682-0377-2015.

13. CUNHA HP, SANTOS AB, FOERSTER SIA, MOURA GJB, LIRA AFA. Can contrasting habitats influence predatory behavior in tropical forest scorpions?. **acta ethol**, v. 25, p. 107–113, 2022. https://doi.org/10.1007/s10211-022-00390-5.

14. DAGLIO LG, DAWSON MN. Integrative taxonomy: ghosts of past, present and future. **Journal of the Marine Biological Association of the United Kingdom**, v 99, n.6, p.1237–46, 2019. https://doi.org/10.1017/S0025315419000201.

15. DEHGHANI R, KASSIRI H, MOHAMMADZADEH N. Comparison of Various Methods of Collecting Scorpions (Arachnida, Scorpiones) in Khuzestan Province, Southwestern Iran. **Arch Clin Infect Dis**, v. 14, n. 4, p. 1-13, 2019. http://dx.doi.org/10.5812/archcid.84452.

16. DIAS NB, SOUZA BM, COCCHI FK, CHALKIDIS HM, DORCE VAC, PALMA MS. Profiling the short, linear, non-disulfide bond-containing peptidome from the venom of the scorpion Tityus obscurus. **Journal of proteomics**, v. 170, p. 70–79, 2018. https://doi.org/10.1016/j.jprot.2017.09.006.

17. FOERSTER SAI, LIRA AFA, ALMEIDA CG. Vegetation structure as the main source of variability in scorpion assemblages at small spatial scales and further considerations for the conservation of Caatinga landscapes. **Neotropical Biology and Conservation,** v. 15, n. 4, p. 533-550, 2020. https://doi.org/10.3897/neotropical.15.e59000.

18. HORTA CCR, MAGALHÃES BF, OLIVEIRA-MENDES BBR, CARMO AO, DUARTE CG, FELICORI LF, ÁVILA RAM, CHÁVEZ-OLÓRTEGUI C, KALAPOTHAKIS E. Molecular, Immunological, and Biological Characterization of Tityus serrulatus Venom Hyaluronidase: New Insights into Its Role in Envenomation. **PLoS Neglected Tropical Diseases**, v. 8, n. 2, p. 1-20, 2014. https://doi.org/10.1371/journal.pntd.0002693.

19. KALAPOTHAKIS Y, MIRANDA K, PEREIRA AH, WITT AS, MARANI C, MARTINS AP, LEAL GH, CAMPOS-JUNIOR, PIMENTA AMC, BORGES A, CHÁVEZ-OLÓRTEGUI C, KALAPOTHAKIS E. Novel components of Tityus serrulatus venom: A transcriptomic approach. **Toxicon**, v. 189, p. 91-104, 2021. https://doi.org/10.1016/j.toxicon.2020.11.001.

Revista ARACÊ
ISSN: 2358-2472

20. LIMA JF, CARVALHO LS, CARVALHO MA, SCHNEIDER MC. Chromosome diversity in Buthidae and Chactidae scorpions from Brazilian fauna: Diploid number and distribution of repetitive DNA sequences. **Genetics and Molecular Biology**, v. 46, n. 2, p. 1-17, 2023. https://doi.org/10.1590/1678-4685-GMB-2022-0083.

21. LIMA JR, SILVA MA, MARTINS RD, JORGE RJB, LIRA AFA. Effect of photoperiod on the biomass and survivorship of juvenile scorpions Jaguajir rochae (Scorpiones, Buthidae). **Acta Scientiarum**. Biological Sciences, v. 44, n. 1, p. 1-16, 2022. https://doi.org/10.4025/actascibiolsci.v44i1.56785.

22. LIRA A., BADILLO-MONTAÑO R, LIRA-NORIEGA A, ALBUQUERQUE C. Potential distribution patterns of scorpions in north-eastern Brazil under scenarios of future climate change. **Austral Ecology**, v. 45, p. 215-228, 2020. https://doi.org/10.1111/aec.12849.

23. LIRA AFA, ALBUQUERQUE CMR. Diversity of scorpions (Chelicerata: Arachnida) in the Atlantic Forest in Pernambuco, northeastern Brazil. **Check List**, v. 10, n. 6, p. 1331-35, 2014. https://doi.org/10.15560/10.6.1331.

24. LIRA AFA, ALMEIDA FMF, ALBUQUERQUE CMR. Reaction under the risk of predation: effects of age and sexual plasticity on defensive behavior in scorpion Tityus pusillus (Scorpiones: Buthidae). **J Ethol**, v. 38, p. 13–19, 2020a. https://doi.org/10.1007/s10164-019-00615-4.

25. LIRA AFA, ARAUJO JC, REGO FNAA, FOERSTER SIA, ALBUQUERQUE CMR. Habitat heterogeneity shapes and shifts scorpion assemblages in a Brazilian seasonal dry tropical forest. **Journal of Arid Environments**, v. 186, p. 1–7, 2021d. https://doi.org/10.1016/j.jaridenv.2020.104413.

26. LIRA AFA, DAMASCENO EM, SILVA-FILHO AAC, ALBUQUERQUE CMR. Linking scorpion (Arachnida: Scorpiones) assemblage with fragment restoration in the Brazilian Atlantic Forest. **Studies on Neotropical Fauna and Environment**, v. 53, n. 2, p. 107–112, 2017b. https://doi.org/10.1080/01650521.2017.1413823.

27. LIRA AFA, FOERSTER SAI, ALBUQUERQUE CMR, MOURA GJB. Contrasting patterns at interspecific and intraspecific levels in scorpion body size across a climatic gradient from rainforest to dryland vegetation. **Zoology**, v. 146, p. 1-6, jun. 2021b. https://doi.org/10.1016/j.zool.2021.125908.

28. LIRA AFA, FOERSTER SIA, SALOMÃO RP, PORTO TJ, ALBUQUERQUE CMR, MOURA GJB. Understanding the effects of human disturbance on scorpion diversity in Brazilian tropical forests. **J Insect Conserv**, v. 25, p. 147–158, 2021. https://doi.org/10.1007/s10841-020-00292-6.

29. LIRA AFA, GUILHERME E, SOUZA MBD, CARVALHO LS. Scorpions (Arachnida, Scorpiones) from the state of Acre, southwestern Brazilian Amazon. **Acta Amazonica**, v. 51, n. 1, p. 58-62, 2021a. https://doi.org/10.1590/1809-4392202001551.

30. LIRA AFA, OLIVEIRA RF, DIONISIO-DA-SILVA W, Moura GJB. Influence of the edge-core gradient on the scorpion assemblage (Arachnida, Scorpiones) in a Brazilian

Revista ARACÊ
ISSN: 2358-2472

Atlantic forest. **Int J Trop Insect Sci**, v. 41, p. 447–454, 2021e. https://doi.org/10.1007/s42690-020-00225-5.

31. LIRA AFA, PORDEUS LM, ALBUQUERQUE CMR. Leucism in Tityus pusillus (Scorpiones: Buthidae): Report of a rare event in scorpions. **Journal of Arachnology**, v. 44, n. 2, p. 245–246, 2016. https://doi.org/10.1636/JoA-S-16-004.

32. LIRA AFA, PORDEUS LM, REGO FNAA, IANNUZZI K, ALBUQUERQUE CMR. Sexual dimorphism and reproductive behavior in the Brazilian scorpion Tityus pusillus (Scorpiones, Buthidae). **Invertebrate Biology**, v. 137, n. 3, p. 221–230, 2018b. https://doi.org/10.1111/ivb.12221.

33. LIRA AFA, PORDEUS LM, SALOMÃO RP, MONTAÑO RB, ALBUQUERQUE CMR. Effects of anthropogenic land-use on scorpions (Arachnida: Scorpiones) in Neotropical forests. **Int J Trop Insect Sci**, v. 39, p. 211–218, 2019b. https://doi.org/10.1007/s42690-019-00029-2.

34. LIRA AFA, REGO FNAA, SALOMÃO RP, ALBUQUERQUE CMR. Effects of habitat quality on body size of the litter dwelling scorpion Tityus pusillus in fragmented rainforests of Brazil. **Journal of Arachnology**, v. 48, n. 3, 2021c. https://doi.org/10.1636/JoA-S-19-081.

35. LIRA AFA, SALOMÃO RP, ALBUQUERQUE CMR. Pattern of scorpion diversity across a bioclimatic dry-wet gradient in Neotropical forests. **Acta Oecologica**, v. 96, p. 10–17, 2019a. https://doi.org/10.1016/j.actao.2019.02.004.

36. LIRA AFA, SANTOS AB, SILVA NA, MARTINS RD. Threat level influences the use of venom in a scorpion species, Tityus stigmurus (Scorpiones, Buthidae). **acta ethologica**, v. 20, n. 3, p. 291–295, 2017c. https://doi.org/10.1007/s10211-017-0274-3.

37. LIRA AFA, SOUZA AM, ALBUQUERQUE CMR. Environmental variation and seasonal changes as determinants of the spatial distribution of scorpions (Arachnida: Scorpiones) in Neotropical forests. **Canadian Journal of Zoology**, v. 96, n. 9, p. 963–972, 2018a. https://doi.org/10.1139/cjz-2017-0251.

38. LIRA AFA, SOUZA AM. Microhabitat use by scorpion species (Arachnida: Scorpiones) in the montane Atlantic Rain Forest, Brazil. **Revista Ibérica de Aracnologia**, n. 24, p. 107-108, 2014. http://sea-entomologia.org/PDF/RIA24/107-108RIA24NC.pdf.

39. LIRA AFA, VIEIRA AGT, OLIVEIRA RF. Seasonal influence on foraging activity of scorpion species (Arachnida: Scorpiones) in a seasonal tropical dry forest remnant in Brazil. **Studies on Neotropical Fauna and Environment**, v. 55, n. 3, p. 226–232, 2020b. https://doi.org/10.1080/01650521.2020.1724497.

40. LIRA, AFA, PORDEUS, LM, BARBIER, E, RODRIGUES, GG. Scorpions (Arachnida, Scorpiones) of an Atlantic forest fragment in the coastalnortheastern Brazil: Barra of Mamanguape river protected área. Arachnida – **Rivista Aracnologica Italiana**, v. 13, p. 22-30, 2017.

Revista ARACÊ
ISSN: 2358-2472

https://www.researchgate.net/publication/318904077_Scorpions_Arachnida_Scorpiones_of_an_Atlantic_forest_fragment_in_the_coastal_northeastern_Brazil_Barra_of_Mamanguape_river_protected_area

41. LOURENÇO WR, CUELLAR O. Scorpions, Scorpionism, Life History Strategies And Parthenogenesis. **J Venom Anim Toxins**. 1995, v. 1, n. 2, p. 51–62, 1995. https://doi.org/10.1590/S0104-79301995000200002.

42. LOURENÇO WR, GIUPPONI APL, LEGUIN EA. Description of three more new species of the genus Ananteris. **An Acad Bras Ciênc**, v. 85, n. 2, p. 709–25, 2013. https://doi.org/10.1590/S0001-37652013000200016.

43. LOURENÇO WR. A new species of Physoctonus Mello-Leitão, 1934 (Scorpiones: Buthidae) from the 'Campos formations' of southern Amazonia. **ZooKeys**, v. 711, p. 67-80, 2017. https://doi.org/10.3897/zookeys.711.20187.

44. LOURENÇO WR. Scorpion incidents, misidentification cases and possible implications for the final interpretation of results. **J Venom Anim Toxins Incl Trop Dis**, v. 22, n. 21, p. 1-13, 2016. https://doi.org/10.1186/s40409-016-0075-6.

45. LOURENÇO WR. Some additional comments on the Ananterinae or'Ananteris group'and description of a new species of Ananteris Thorell, 1891 from Central Brazil (Scorpiones: Buthidae). **Zootaxa**, v. 4984, n. 1, p. 347-356, 2021. https://doi.org/10.11646/zootaxa.4984.1.25.

46. LOURENÇO WR. Why does the number of dangerous species of scorpions increase? The particular case of the genus Leiurus Ehrenberg (Buthidae) in Africa. **Journal of Venomous Animals and** case of the genus Leiurus Ehrenberg (Buthidae) in Africa. **Journal of Venomous Animals and Toxins Including Tropical Diseases**, v. 26, p. 1-15, 2020. https://doi.org/10.1590/1678-9199-JVATITD-2020-0041.

47. LOURENÇO, W.R. 2002. **Scorpions of Brazil Les Édition de l'If**, Paris, 308p
.

48. MAGALHÃES ACM, SANTANA CJC, MELANI RD, DOMONT GB, CASTRO MS, FONTES W, ROEPSTORFF P, PIRES JÚNIOR OR. Exploring the biological activities and proteome of Brazilian scorpion Rhopalurus agamemnon venom. **Journal Of Proteomics**, v. 237, p. 1-11, 2021. https://doi.org/10.1016/j.jprot.2021.104119.

49. MARTINS APV, CARMO AO, MESQUITA FO, PIMENTA RJG, CHAGAS ATA, KALAPOTHAKIS E. Many unique characteristics revealed by the complete mitochondrial genome of the scorpion Tityus serrulatus (Lutz e Mello 1922) (Chelicerata; Arachnida). **Mitochondrial DNA.** v. 27, n. 5, p. 3628–29, 2015. https://doi.org/10.3109/19401736.2015.1079828.

50. MATTONI CI, GARCÍA-HERNÁNDEZ S, BOTERO-TRUJILLO R, OCHOA JA, OJANGUREN-AFFILASTRO AA, ROCHA RP, PRENDINI L. Scorpion Sheds "Tail" to Escape: Consequences and Implications of Autotomy in Scorpions (Buthidae: Ananteris). **PLOS ONE**, v. 10, n. 1, p. 1-10, 2015. https://doi.org/10.1371/journal.pone.0116639.

Revista ARACÊ
ISSN: 2358-2472

51. MATTOS VF, CARVALHO LS, CARVALHO MA, SCHNEIDER MC. Insights into the origin of the high variability of multivalent-meiotic associations in holocentric chromosomes of Tityus (Archaeotityus) scorpions. **PloS one**, v. 13, n. 2, p. 1-11, 2018. https://doi.org/10.1371/journal.pone.0192070.

52. MATTOS VF, CELLA DM, CARVALHO LS, CÂNDIDO DM, SCHNEIDER MC. High chromosome variability and the presence of multivalent associations in buthid scorpions. **Chromosome Research**, v. 21, n. 2, p. 121–136, 2013. https://doi.org/10.1007/s10577-013-9342-3.

53. OTT R, OTT AP. Abundance and seasonality of Bothriurus signatus (Arachnida, Scorpiones) in different vegetal formations in Sao Francisco de Paula, RS, Brazil. **Iheringia. Série Zoologia**, v. 104, n. 1, p. 92–98, 2014. https://doi.org/10.1590/1678-4766201410419298.

54. PARDAL PPDO, COELHO JS, SILVA JMD, ALMEIDA BRR, CHALKIDIS HM, BORGES A, ISHIKAWA EAY, SANTOS- NETO GC, MELO MADD. Interpopulational genetic diversity in the medically important scorpion Tityus obscurus (Scorpiones: Buthidae) from northeastern Brazilian Amazonia. **Acta Amazonica**, v. 53, n. 3, p. 215-22, 2023. https://doi.org/10.1590/1809-4392202202441.

55. PESSOA VB, MOURA GJB, LIRA AFA. Influence of predator density in foraging behavior and microhabitat choice on litter-dwelling scorpions. **Neotropical Biodiversity**, v. 8, n. 1, 297–300, 2022. https://doi.org/10.1080/23766808.2022.2126020.

56. PORDEUS LM, LIRA AFA, ALBUQUERQUE CMR. Male courtship behavior is triggered by female chemical cues in the scorpion Tityus pusillus (Scorpiones: Buthidae). **Canadian Journal of Zoology**, v. 97, n. 12, p. 1122–1125, 2019. https://doi.org/10.1139/cjz-2019-0020.

57. SANTOS DS, CARVALHO EL, LIMA JC, BREDA RV, OLIVEIRA RS, FREITAS TC, SALAMONI SD, DOMINGUES MF, PIOVESAN AR, BOLDO JT, ASSIS DR, COSTA JC, DAL BELO CA, PINTO PM. Bothriurus bonariensis scorpion venom activates voltage-dependent sodium channels in insect and mammalian nervous systems. **Chemico-Biological Interactions**, v. 258, p. 1–9, 2016. https://doi.org/10.1016/j.cbi.2016.08.008.

58. SANTOS GCSG, DIONISIO-DA-SILVA W, SOUZA-ALVES JP, ALBUQUERQUE CMR, LIRA AFA. Random or clumped: How litter dwelling scorpions are distributed in a fragment of Brazilian Atlantic forest. **European Journal of Entomology**, v. 115, p. 445–449, 2018. https://www.eje.cz/artkey/eje-201801-0045_Random_or_clumped_How_litter_dwelling_scorpions_are_distributed_in_a_fragment_of_Brazilian_Atlantic_forest.php.

59. SANTOS MDS, PORTO TJ, LIRA-DA-SILVA RW, BRASIL TK. Description of the male of Tityus kuryi Lourenço, 1997 and notes about males of Tityus stigmurus (Thorell, 1877) and Tityus serrulatus Lutz & Mello, 1922 (Scorpiones, Buthidae). **ZooKeys**, v. 435, p. 49–61, 2014. https://doi.org/10.3897/zookeys.435.6694.

Revista ARACÊ
ISSN: 2358-2472

60. SCHWARTZ EF, BARTOK A, SCHWARTZ CA, PAPP F, GÓMEZ-LAGUNAS F, PANYI G, POSSANI LD. OcyKTx2, a new K+-channel toxin characterized from the venom of the scorpion Opisthacanthus cayaporum. **Peptides**, v. 46, p. 40–46, 2013. https://doi.org/10.1016/j.peptides.2013.04.021.

61. SILVA AAD, AMORIM EM, PEREIRA MG, SANTANA SL, SILVA MAD, LIRA AFA, ROHDE C. Genotoxic effects of anthropogenic environments in the leaf litter-dwelling scorpion Tityus pusillus Pocock, 1893 (Scorpiones; Buthidae). **Mutation research**, v. 887, n. 503585, p. 1-13, 2023. https://doi.org/10.1016/j.mrgentox.2023.503585.

62. SILVA APS, CANDIDO DM, NENCIONI ALA, KIMURA LF, PREZOTTO-NETO JP, BARBARO, KC, CHALKIDIS HM, DORCE VAC. Some pharmacological effects of Tityus obscurus venom in rats and mice. **Toxicon**, v.126, p. 51–58, 2017. https://doi.org/10.1016/j.toxicon.2016.12.008.

63. SILVA MA, SILVA NA, LIRA AFA, MARTINS RD. Role of venom quantity in the feeding behavior of Jaguajir rochae (Scorpiones: Buthidae). **acta ethologica**, v. 22, n. 2, p. 99–104, 2019. https://doi.org/10.1007/s10211-019-00312-y.

64. SILVA WD, LIRA AFA, ALBUQUERQUE CMR. Distinct edge effects and reproductive periods of sympatric litter-dwelling scorpions (Arachnida: Scorpiones) in a Brazilian Atlantic forest. **Zoology** v. 129, p. 17–24, 2018. https://doi.org/10.1016/j.zool.2018.06.001.

65. SOUZA AM, SANTANA-NETO PL, LIRA AFA, ALBUQUERQUE CMR. Growth and developmental time in the parthenogenetic scorpion Tityus stigmurus (Thorell, 1876) (Scorpiones: Buthidae). **Acta Scientiarum. Biological Sciences**, v. 38, n. 1, p. 85–90, 2016. https://www.redalyc.org/journal/1871/187146621011/.

66. YAMAZAKI L, VINDICA VF, MARQUES MI, BATTIROLA LD. Arthropods associated with Callisthene fasciculata (Vochysiaceae) canopy in the Pantanal of Mato Grosso, Brazil. **Revista Colombiana De Entomologia**, v. 46, n. 1, p. 1-7, 2020. https://doi.org/10.25100/socolen.v46i1.10168.