

Rapid Communication

Alien scorpions in the Municipality of São Paulo, Brazil – evidence of successful establishment of *Tityus stigmurus* (Thorell, 1876) and first records of *Broteochoactas parvulus* Pocock, 1897, and *Jaguajir rochae* (Borelli, 1910)

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Abstract

We report the successful introduction and invasion of the scorpion species, *Tityus stigmurus* (Thorell, 1876), in São Paulo municipality, Brazil, more than 1,000 km from its southern-most record. The species has considerable impacts on human health, because of its venomous sting. The first specimen appeared in 2012, and by the end of 2015, three populations were identified, with 86 records so far. They were probably introduced via the fruit trade. Two other alien scorpion species were recorded in São Paulo, including a single specimen of *Broteochoactas parvulus* Pocock, 1897, and two specimens of *Jaguajir rochae* (Borelli, 1910).

Key words: fruit trade, invasive species, synanthropic, venomous species

Introduction

Invasive alien species are a constant threat to the local biodiversity, economy, and human health (Elton 1958; Early et al. 2016). Some of these invasive species are venomous animals, such as scorpions (Benton 1991; Toscano-Gadea 1998; Freitas and Vasconcelos 2008). These arachnids are among the primary causes of human envenomation and are mostly distributed in tropical and subtropical regions of the world (Chippaux and Goyffon 2008). They are easily transported to distant countries by human activities (Freitas and Vasconcelos 2008). However, successful introduction of scorpions is rarely recorded. *Euscorpis flavicaudis* (De Geer, 1778)

was introduced into England (Benton 1991) and Uruguay (Toscano-Gadea 1998), and *Isometrus maculatus* (De Geer, 1778) is now a pan-tropical species (Lourenço 2002). In Brazil, *Tityus stigmurus* (Thorell, 1876) was introduced in the island of Fernando de Noronha (Freitas and Vasconcelos 2008). The parthenogenetic and medically important *Tityus serrulatus* (Lutz and Mello, 1922) has expanded considerably from its original geographical distribution to the north and southern parts of Brazil. Single individuals as well as small to large populations of *T. serrulatus* are found hundreds of kilometers away from its previously known geographic range (Eickstedt et al. 1996; Bortoluzzi et al. 2007; Rosa et al. 2015).

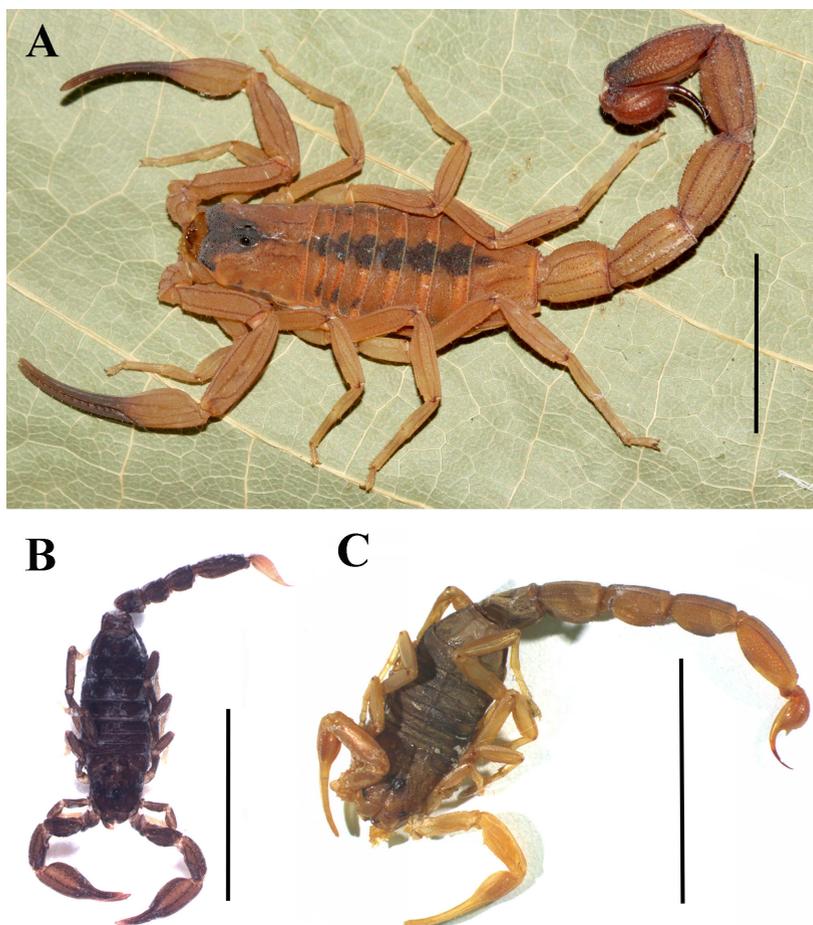


Figure 1. Alien scorpions collected in São Paulo, state of São Paulo, Brazil. A: living *Tityus stigmurus* (Thorell, 1876); B: preserved *Broteoactas parvulus* Pocock, 1897; C: preserved *Jaguajir rochae* (Borelli, 1910). Scale bar = 10 mm. Photos: R. Bertani.

Herein, we report the successful introduction of *Tityus stigmurus* (Figure 1A), a medically important species, originally distributed in the northeastern parts of Brazil (Figure 2A), in three urban areas in the Municipality of São Paulo, state of São Paulo, Brazil (Figure 2B). Records of the alien scorpions *Broteoactas parvulus* Pocock, 1897, and two specimens of *Jaguajir rochae* (Borelli, 1910) in São Paulo are also presented here (Figures 1B–C).

Material and methods

Study site

The municipality of São Paulo is one of the most densely populated regions in the world, with approximately 12 million people living within a 1,521 km² (IBGE 2016) area. It is a plateau, ca. 900 m asl, having originally a mosaic of open fields and Brazilian Atlantic Forest. The region is also crossed by two main rivers. Historically, there were important areas with riparian vegetation and swamps (Usteri 1911;

Garcia and Pirani 2005). The areas where *T. stigmurus* (Figure 1A) specimens were found are highly urbanized (Figure 3).

Sampling and species identification

Scorpion records were obtained from three sources in the period between May/2012 to December/2015. Either the scorpions were donated spontaneously by the citizens to the CCZ – Centro de Controle de Zoonoses (Center for Zoonosis Control), São Paulo Municipality, state of São Paulo, Brazil, and SUVIS – Supervisão de Vigilância em Saúde (Regionalized Services of Health Surveillance), São Paulo Municipality, State of São Paulo, Brazil, or the scorpions were collected by the municipality agents as a part of a larger anti-scorpion program carried out monthly (CCZ), or as a result of requests by the population for local inspection conducted by SUVIS. Specimens are deposited at the Coleção de Fauna Sinantrópica do Município de São Paulo, Labfauna, – Laboratório de Identificação e Pesquisa em Fauna Sinantrópica

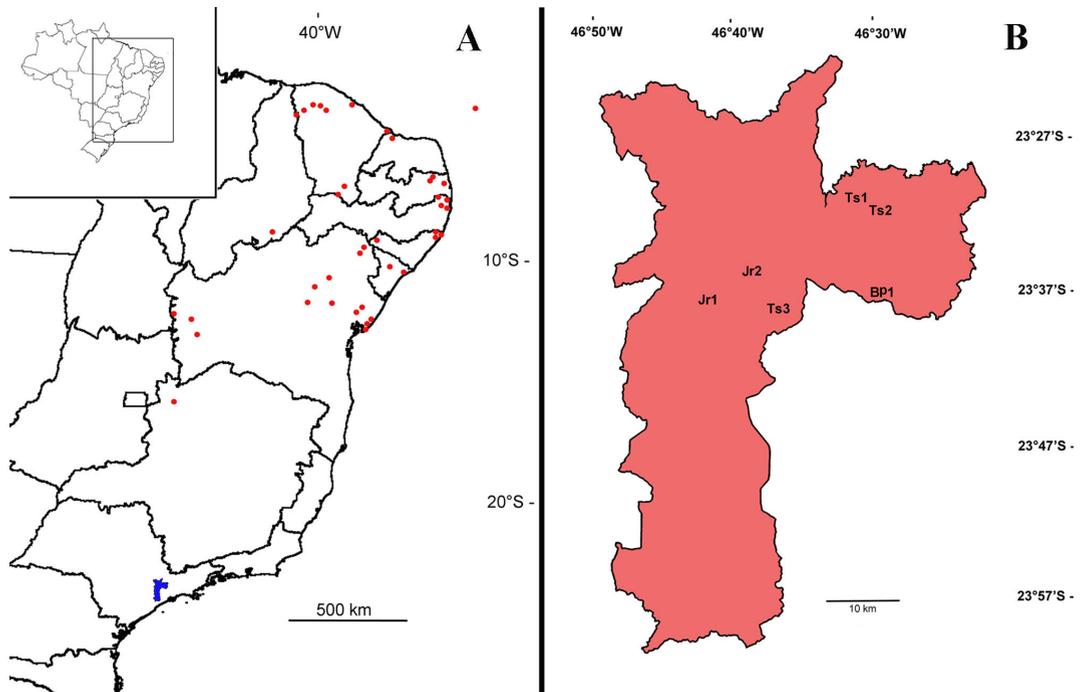


Figure 2. A: Map of Brazil showing published records for *Tityus stigmurus* (Thorell, 1876) (red dots) distribution and the location of the Municipality of São Paulo (blue). Records are based on Souza et al. (2009) and Santos et al. (2014). B: Map of the municipality of São Paulo indicating the records of alien *Tityus stigmurus* (Thorell, 1876) (Ts1-3), *Jaguajir rochae* (Borelli, 1910) (Jr1-2), and *Broteochactas parvulus* Pocock, 1897 (Bp1).

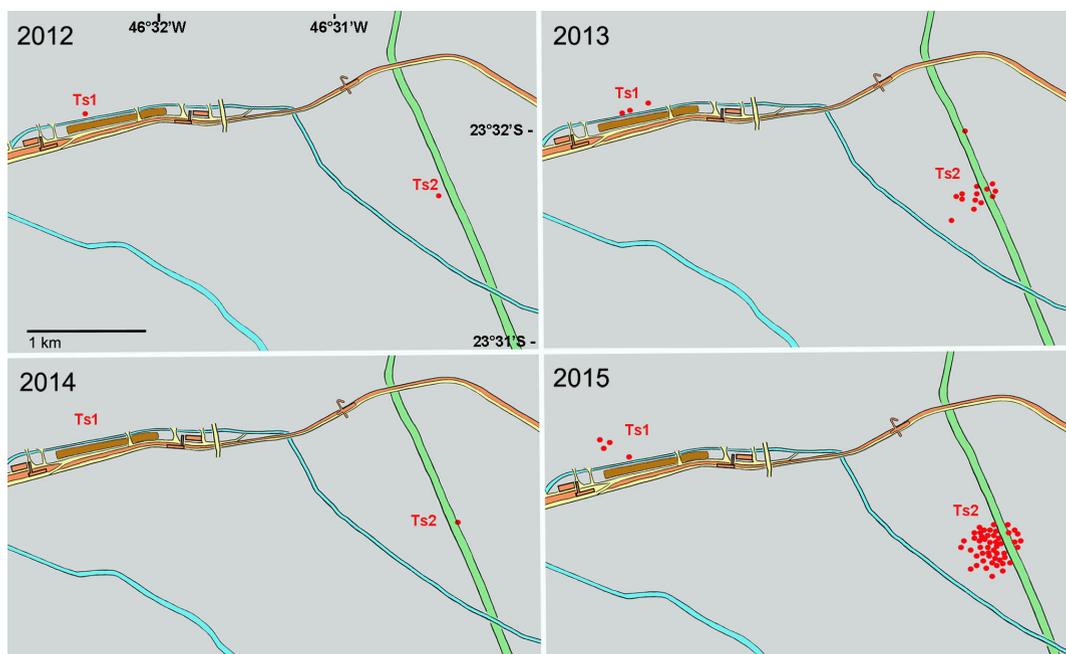


Figure 3. Records of *Tityus stigmurus* (Thorell, 1876) (red dots) for two areas (Ts1 and Ts2) in the eastern region of São Paulo Municipality. The main streets and bridges are shown in yellow; the Metro and railway systems are in orange; the main rivers are in blue; the large empty area with low vegetation coverage and used for high voltage power towers is in green; and the anti-flood area is depicted in brown.

(Laboratory for the Identification of and Research into Synanthropic Fauna), CCZ, São Paulo Municipality, State of São Paulo, Brazil (CFS-SP, Marco Otávio de Matos Júnior). The specimens were identified using the keys and diagnoses based on Lourenço (2002).

Results

Three species of non-indigenous scorpions were recorded for the first time in the São Paulo Municipality: *Broteoactas parvulus* Pocock, 1897 (Chactidae) (Figure 1B); *Jaguajir rochae* (Borelli, 1910) (Figure 1C), and *Tityus stigmurus* (Buthidae) (Figure 1A). A single specimen of *Broteoactas parvulus* Pocock, 1897 was recorded in a house located in the extreme east of the municipality, close to a milk box which was recently brought from a market, in February 2012 (Figures 1B, 2B, Supplementary material Table S1). Two specimens of *J. rochae* were found in central-southern São Paulo (Figures 1C, 2B) on November 29, 2010, and on June 3, 2013. Both specimens were found in public schools, one individual was crawling inside the building and the other was coming out of a recently opened box containing melons (Table S1). There were 86 records of *T. stigmurus* between May 8, 2012 and December 16, 2015, totaling 180 specimens in the three areas (Ts1–3) (Table S2).

Specimens of areas Ts1 (N = 8) and Ts2 (N = 76) were recorded inside pluvial galleries (Ts1 = 37.5%, N = 3; Ts2 = 64.47%, N = 49), houses or backyards (Ts1 = 62.5%, N = 5; Ts2 = 19.74%, N = 15), public schools (Ts2 = 10.53%, N = 8), or in other places (Ts2 = 5.26%, N = 4). In area Ts3, one specimen was collected from a house and another from a pluvial gallery. There was a bias towards pluvial galleries since they are routinely inspected as part of the anti-scorpion program managed by CCZ and SUVIS.

The *T. stigmurus* specimens (86 records) were either sent by citizens (Ts1 = 37.5%, N = 3; Ts2 = 22.37%, N = 17) or collected by municipality agents of the anti-scorpion program (CCZ, SUVIS) (Ts1 = 62.5%, N = 5; Ts2 = 77.63%, N = 59). The two specimens in area Ts3 were collected by municipality agents. Specimens in all developmental stages were found in areas Ts1 and Ts2.

The first *T. stigmurus* specimen was recorded in area Ts1, near a school in May 2012 (Figure 3). A few months later (December 2012), another specimen was recorded inside a school, but 2.5 km away from the first area (Ts2) (Figure 3). We revisited areas Ts1 and Ts2 in 2012 but no additional specimens were found. Other records appeared in the beginning of 2013. In the second semester (late winter

to spring and beginning of summer) the records increased considerably (Table S2, Figure 3). In 2014, we had a single record of 3 specimens (Table S2, Figure 3). However, the following year, with a more intense search, we obtained 59 records of 138 specimens, mostly from the pluvial system (Table S2, Figure 3). Recently, in the first semester of 2015, area Ts3 had two additional records.

Discussion

Over the four-year study period, we compiled the records of scorpion species from two areas in the eastern Municipality of São Paulo. The increase in the number of collected specimens during this period and the presence of females carrying young scorpions in their dorsum suggest that *T. stigmurus* have reproduced, providing evidence that this species is already established in the regions Ts1–2.

Tityus stigmurus is the second species of non-indigenous *Tityus* to become established in the Municipality of São Paulo (after *T. serrulatus* Eickstedt et al. 1996). Compared to the indigenous species, *Tityus costatus* (Karsch, 1879) and *Tityus bahiensis* (Perty, 1833), *T. serrulatus* is the most medically important species in Brazil, and has reached the municipality after geographic distribution extension (Eickstedt et al. 1996). However, contrary to this species, the southernmost record of *T. stigmurus* was ca. 1,000 km from São Paulo (Souza et al. 2009; Santos et al. 2014). Therefore, presumably it was introduced passively. Despite the local climate being significantly colder and more humid than that in its original habitat (northeastern parts of Brazil), the species thrived under these modified conditions. The species is known to live in the urban areas in the northeastern parts of Brazil (Albuquerque et al. 2009) and its natural region of origin is not fully resolved. The wide distribution showed by *T. stigmurus* in northeastern Brazil (Figure 2A) is definitely artificial, reflecting the expansion, introduction, and adaptation that allows the scorpions (for example *T. serrulatus*) to live and reproduce in the neighboring urban areas (Eickstedt et al. 1996). Their ability to survive harnessing the perturbations of the environment is a critical factor that facilitated the successful introduction of *T. stigmurus* in São Paulo. Similar to *T. serrulatus*, *T. stigmurus* is also parthenogenetic, with a few recorded sexual populations (Ross 2010; Santos et al. 2014). Hence, even a few individuals can successfully establish a new population.

The record of three distinct populations of *Tityus stigmurus* raises the question as to whether this species was introduced once or in three independent events. The more recent record (Ts3) in central-

southern São Paulo suggests that it was an independent event, since the distance to the other records (Ts1 and Ts2) in the eastern region (ca. 14 km in straight line) was significant. On the other hand, the two areas in the eastern region were separated by only 2.5 km (shortest distance), which suggests the possibility of a single introductory event. However, we did not find any specimen in the region between the two areas, despite several attempts, reinforcing the hypothesis of distinct introductions. The origin of the specimens is presumably the northeastern part of Brazil, an area known for the presence of this species (Figure 2A). An underlying factor common to all records (except area Ts3, but including *J. rochae* records) is trade, specifically the routes of fruit trade. The two *J. rochae* specimens were both found in schools, and one of them was coming out of a box of melons. One of the main areas of melon production in Brazil is the northeastern region, which is inhabited by *J. rochae*. The same region is also within the native range of *T. stigmurus*. The two first records in areas Ts1 and Ts2, were inside or close to schools, which normally receive fruits from government programs for student nutrition. The trade of fruits is an important route via which international alien spider transport occurs (Vetter et al. 2014); therefore, it is likely that the same route could be attributed to the introduction of *T. stigmurus* in São Paulo.

São Paulo Municipality now has three *Tityus* species (*T. bahiensis*, *T. serrulatus*, and *T. stigmurus*), which pose considerable medical concern. This information must be broadly shared with the local medical care institutions so that they can identify *T. stigmurus* specimens and treat their envenomation cases. Our findings show that *Tityus stigmurus* colonizes urban areas with very distinct climate from its indigenous geographical distribution, it can be considered an invasive species, and immediate control actions must be implemented after its first appearance.

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References

- Albuquerque CMR, Barbosa MO, Iannuzzi L (2009) *Tityus stigmurus* (Thorell, 1876) (Scorpiones: Buthidae): response to chemical control and understanding of scorpionism among the population. *Revista da Sociedade Brasileira de Medicina Tropical* 42: 255–259, <https://doi.org/10.1590/S0037-86822009000300004>
- Benton TG (1991) The life history of *Euscorpium flavicaudis* (Scorpiones, Chactidae). *The Journal of Arachnology* 19: 105–110. http://www.americanarachnology.org/JoA_free/JoA_v19_n2%20JoA_v19_p105.pdf (accessed 11 December 2017)
- Bortoluzzi LR, Querol MVM, Querol E (2007) Notas sobre a ocorrência de *Tityus serrulatus* Lutz & Mello, 1922 (Scorpiones, Buthidae) no oeste do Rio Grande do Sul, Brasil. *Biota Neotropica* 7, <https://doi.org/10.1590/S1676-06032007000300036>
- Chippaux JP, Goyffon M (2008) Epidemiology of scorpionism: a global appraisal. *Acta Tropica* 107: 71–79, <https://doi.org/10.1016/j.actatropica.2008.05.021>
- Early R, Bradley BA, Dukes JS, Lawler JJ, Olden JD, Blumenthal DM, Gonzalez P, Grosholz ED, Ibañez I, Miller LP, Sorte CJB, Tatem AJ (2016) Global threats from invasive alien species in the twenty-first century and national response capacities. *Nature Communications* 7: 12485, <https://doi.org/10.1038/ncomms12485>
- Eickstedt VRD, Ribeiro LA, Candido DM, Albuquerque MJ, Jorge MT (1996) Evolution of scorpionism by *Tityus bahiensis* (Perty) and *Tityus serrulatus* Lutz and Mello and geographical distribution of the two species in the state of São Paulo- Brazil. *Journal of Venomous Animals and Toxins* 2, <https://doi.org/10.1590/S0104-79301996000200003>
- Elton CS (1958) *The Ecology of Invasions by Animals and Plants*. Methuen, London, England, 181 pp, <https://doi.org/10.1007/978-1-4899-7214-9>
- Freitas GCC, Vasconcelos SD (2008) Scorpion fauna of the island of Fernando de Noronha, Brazil: first record of *Tityus stigmurus* (Thorell 1877) (Arachnida, Buthidae). *Biota Neotropica* 8, <https://doi.org/10.1590/S1676-06032008000200019>
- Garcia RJF, Pirani JR (2005) Análise florística, ecológica e fitogeográfica do Núcleo Curucutu, Parque Estadual da Serra do Mar (São Paulo, SP), com ênfase nos campos junto à crista da Serra do Mar. *Hoehnea* 32: 1–48, http://arquivos.ambiente.sp.gov.br/hoehnea/2016/12/321_T01_24_07_2015-2.pdf (accessed 11 December 2017)
- IBGE – Instituto Brasileiro de Geografia e Estatística (2016) <http://cod.ibge.gov.br/493> (accessed 25 October 2016)
- Lourenço WR (2002) *Scorpions of Brazil*. Les Éditions de l’If, Paris, France, 306 pp
- Rosa CM, Abegg AD, Borges LM, Bitencourt GSS, Di Mare RA (2015) New record and occurrence map of *Tityus serrulatus* Lutz & Mello, 1922 (Scorpiones, Buthidae) in the state of Rio Grande do Sul southern Brazil. *Check List* 11: 1556, <https://doi.org/10.15560/11.1.1556>
- Ross LK (2010) Confirmation of parthenogenesis in the medically significant, synanthropic scorpion *Tityus stigmurus* (Thorell, 1876) (Scorpiones: Buthidae). *Revista Ibérica de Aracnologia* 18: 115–121. <http://sea-entomologia.org/Publicaciones/RevistaIbericaAracnologia/RIA18/115-122NBrevePartenogenesisTityus.pdf> (accessed 11 December 2017)
- Santos MDS, Porto TJ, Lira-da-Silva RM, Brazil TK (2014) 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* 435: 49–61, <https://doi.org/10.3897/zookeys.435.6694>
- Souza CAR, Candido DM, Lucas SM, Brescovit AD (2009) On the *Tityus stigmurus* complex (Scorpiones, Buthidae). *Zootaxa* 1987: 1–38
- Toscano-Gadea CA (1998) *Euscorpium flavicaudis* (de Geer, 1778) in Uruguay: first record from the New World. *Newsletter of the British Arachnological Society* 81: 6
- Usteri A (1911) Flora der Umgebung der Stadt São Paulo. G. Fischer, Jena, Germany, 271 pp

Vetter RS, Crawford RL, Buckle DJ (2014) Spiders (Araneae) found in bananas and other international cargo submitted to North

American arachnologists for identification. *Journal of Medical Entomology* 51: 1136–1143, <https://doi.org/10.1603/ME14037>

Supplementary material

The following supplementary material is available for this article:

Table S1. *Jaguajir rochae* (Borelli, 1910) (Jr) and *Broteochactas parvulus* Pocock, 1897 (Bp) records (specimens) in São Paulo Municipality.

Table S2. *Tityus stigmurus* (Thorell, 1876) records (specimens) from 2012 to 2015 in three areas (Ts1, Ts2, and Ts3) in São Paulo Municipality.

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http://www.reabic.net/journals/bir/2018/Supplements/BIR_2018_Bertani_etal_SupplementaryTables.xlsx