Research Article / Artículo de Investigación

Spatiotemporal dynamics of triatomines (Hemiptera: Triatominae), vectors of Chagas disease in Sergipe, Brazil (2005-2023)

Dinámica espacio-temporal de triatominos (Hemiptera: Triatominae), vectores de la enfermedad de Chagas en Sergipe, Brasil (2005-2023)

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Abstract. Chagas disease remains a significant public health challenge in Brazil, especially in the state of Sergipe, where vector transmission continues to be the main route of infection. This study analyzed the spatiotemporal distribution of triatomines between 2005 and 2023, using historical data from the Central Public Health Laboratory of Sergipe (LACEN/SE). A total of 2,498 triatomines were collected from 1,353 households, with a predominance of captures in the intradomiciliary environment (67.9%). Most specimens were adults (86.7%). The most frequent species were *Triatoma pseudomaculata* (41.2%), *Panstrongylus lutzi* (24.1%), *Triatoma brasiliensis* (17.5%), and *Panstrongylus megistus* (10.7%). The intradomiciliary infestation averaged 88.9%, reaching 100% in some years, while peridomiciliary infestation was 14.6%. The Mann-Whitney test indicated significant differences in species distribution between intra- and peridomiciliary environments. An average annual decline of 13.49 triatomines was observed in the number of kissing bugs collected in households, according to the slope coefficient of the simple linear regression ($r^2 = 0.6859$; $p < 0.001$). Furthermore, simple linear regression analysis revealed a positive trend between the number of triatomines collected and the number of notified households over the years. Annual fluctuations in the number of triatomines captured were also observed, with a peak in 2009 and the lowest record in 2023. The results highlight the need to strengthen surveillance actions, vector control measures, and community education strategies adapted to the local context to prevent the transmission of Chagas disease.

Key words: Entomological surveillance; epidemiology; geographic distribution; public health; vector control.

Resumen. La enfermedad de Chagas sigue siendo un desafío significativo de salud pública en Brasil, especialmente en el estado de Sergipe, donde la transmisión vectorial continúa siendo la principal vía de infección. Este estudio analizó la distribución espacio-temporal de los triatominos entre 2005 y 2023, utilizando datos históricos del Laboratorio Central de Salud Pública de Sergipe (LACEN/SE). Se recolectó un total de 2.498 triatominos en 1.353 viviendas, con predominio de capturas en

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el ambiente intradomiciliario (67,9%). La mayoría de los especímenes eran adultos (86,7%). Las especies más frecuentes fueron *Triatoma pseudomaculata* (41,2%), *Panstrongylus lutzi* (24,1%), *Triatoma brasiliensis* (17,5%) y *Panstrongylus megistus* (10,7%). La infestación intradomiciliaria presentó un promedio de 88,9%, alcanzando el 100% en algunos años, mientras que la infestación peridomiciliaria fue del 14,6%. La prueba de Mann-Whitney indicó diferencias significativas en la distribución de especies entre los ambientes intra y peridomiciliarios. Se observó una disminución anual promedio de 13,49 triatominos en el número de vinchucas recolectadas en las viviendas, según el coeficiente de pendiente de la regresión lineal simple ($r^2 = 0{,}6859$; $p < 0{,}001$). Además, el análisis de regresión lineal simple reveló una tendencia positiva entre el número de triatominos recolectados y el número de viviendas notificadas a lo largo de los años. También se observaron fluctuaciones anuales en el número de triatominos capturados, con un pico en 2009 y el registro más bajo en 2023. Los resultados resaltan la necesidad de fortalecer las acciones de vigilancia, las medidas de control vectorial y las estrategias de educación comunitaria adaptadas al contexto local para prevenir la transmisión de la enfermedad de Chagas.

Palabras clave: Control vectorial; distribución geográfica; epidemiología; salud pública; vigilancia entomológica.

Introduction

Considered a Neglected Tropical Disease by the World Health Organization, Chagas disease is caused by the protozoan *Trypanosoma cruzi* (Chagas, 1909) and remains a serious public health issue today (WHO 2023). It is estimated that globally, between six and seven million people are infected, with approximately 5.7 million residing in 21 Latin American countries. In Brazil, around 1.2 million people are affected by the infection (WHO 2023).

Chagas disease has multiple transmission routes, with vector transmission, mediated by hematophagous insects known as triatomines, being considered the classic and most significant mode of infection in humans (Souza *et al*. 2024). This transmission is facilitated by the high diversity of existing species, with 158 blood-sucking triatomine species currently known, all of which have the potential to act as vectors of the parasite. In Brazil, 64 species have been identified, 27 of which occur in the northeastern region (Galvão *et al*. 2024).

Northeastern Brazil is epidemiologically significant for the vector transmission of Chagas disease due to the wide distribution of native species that actively participate in transmission cycles, such as *Triatoma brasiliensis* Neiva, 1911, *Triatoma pseudomaculata* Corrêa & Espínola, 1964, *Panstrongylus lutzi* Neiva & Pinto, 1926, and *Rhodnius nasutus* Stål, 1859 (Sarquis *et al*. 2012). Among these species, *T. pseudomaculata* and *T. brasiliensis* stand out due to their wide distribution, with the latter being considered the most important vector of *T. cruzi* transmission and the most challenging to control (Costa *et al*. 2013, 2014).

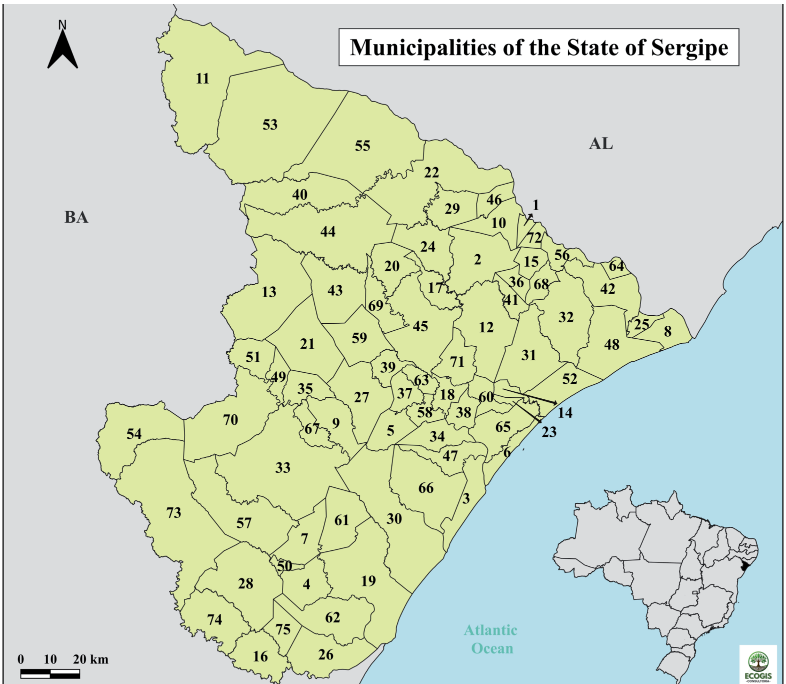
In the state of Sergipe, Chagas disease remains a challenge for municipal health services, which face difficulties in vector surveillance and in identifying and controlling insects present in an around homes, especially in rural areas where housing conditions and limited access to trained teams hinder effective prevention and controls actions (Fontes *et al*. 2024). To date, 12 triatomine species have been identified in the state: *Panstrongylus geniculatus* (Latreille, 1811), *P. lutzi* (Neiva & Pinto, 1923), *P. megistus* (Burmeister, 1835), *Panstrongylus tibiamaculatus* (Pinto, 1926), *Psammolestes tertius* Lent & Jurberg, 1965, *Rhodnius neglectus* Lent, 1954, *T. brasiliensis*, *Triatoma infestans* (Klug, 1834), *Triatoma melanocephala* Neiva & Pinto, 1923, *Triatoma petrocchiae* Pinto & Barreto, 1925, *T. pseudomaculata*, *Triatoma rubrofasciata* (De Geer, 1773), and *Triatoma sordida* (Stål, 1859) (Galvão *et al*. 2024).

Despite advances in biological, ecological, and taxonomic studies on vector species present in Sergipe, gaps remain in the knowledge of epidemiological data related to the progression of Chagas disease (Melo *et al.* 2018; Oliveira *et al*. 2021; Fontes *et al*. 2024). These gaps hinder the development of effective vector control and prevention strategies, as well as limit the analysis of the impact of triatomine populations on public health in Sergipe. Given this context, the objective of this study was to analyze the spatiotemporal distribution of triatomines in Sergipe between 2005 and 2023, aiming to improve the understanding of their dynamics and support the implementation of more effective public policies to combat Chagas disease in the state.

Materials and Methods

Study Area

The state of Sergipe, located in the Northeast region of Brazil, has an area of 21,938.188 km², making it the smallest state in the federation. It comprises 75 municipalities and has an estimated population of 2,210,004 inhabitants (IBGE 2022). Sergipe borders the state of Alagoas to the north, the Atlantic Ocean to the east, and the state of Bahia to the south and west (IBGE 2022) (Fig. 1).



1- Amparo de São Francisco	20- Feira Nova	39- Moita Bonita	58- Riachuelo
2- Aquidabã	21- Frei Paulo	40- Monte Alegre de Sergipe	59- Ribeirópolis
3- Aracaju	22- Gararu	41- Muribeca	60- Rosário do Catete
4- Arauá	23- General Maynard	42- Neópolis	61- Salgado
5- Areia Branca	24- Gracho Cardoso	43- Nossa Senhora Aparecida	62- Santa Luzia do Itanhy
6- Barra dos Coqueiros	25- Ilha das Flores	44- Nossa Senhora da Glória	63- Santa Rosa de Lima
7- Boquim	26- Indiaroba	45- Nossa Senhora das Dores	64- Santana do São Francisco
8- Brejo Grande	27- Itabaiana	46- Nossa Senhora de Lourdes	65- Santo Amaro das Brotas
9- Campo do Brito	28- Itabaianinha	47- Nossa Senhora do Socorro	66- São Cristóvão
10- Canhoba	29- Itabi	48- Pacatuba	67- São Domingos
11- Canindé de São Francisco	30- Itaporanga d'Ajuda	49- Pedra Mole	68- São Francisco
12- Capela	31- Japaratuba	50- Pedrinhas	69- São Miguel do Aleixo
13- Carira	32- Japoatã	51- Pinhão	70- Simão Dias
14- Carmópolis	33- Lagarto	52- Pirambu	71- Siriri
15- Cedro de São João	34- Laranjeiras	53- Poço Redondo	72- Telha
16- Cristinápolis	35- Macambira	54- Poço Verde	73- Tobias Barreto
17- Cumbe	36- Malhada dos Bois	55- Porto da Folha	74- Tomar do Geru
18- Divina Pastora	37- Malhador	56- Propriá	75- Umbaúba
19- Estância	38- Maruim	57- Riachão do Dantas	

Figure 1. Location of the municipalities that make up the state of Sergipe, Brazil. / **Figura 1.** Ubicación de los municipios que conforman el estado de Sergipe, Brasil.

Study design

This study follows a retrospective design based on a historical data series on triatomine collection, conducted by the Central Public Health Laboratory of Sergipe (LACEN-SE) from 2005 to 2023.

The database used in this research included triatomines passively delivered to the Parasitology Laboratory of LACEN-SE by municipal health departments in the state of Sergipe and members of civil society.

Taxonomic identification of triatominae

All triatomines were examined under a stereomicroscope for morphological identification, following the dichotomous keys and taxonomic descriptions provided by Lent and Wygodzinsky (1979).

Diagnosis of Natural infection by *Trypanosoma cruzi* - like

To determine the natural infection of triatomines by *Trypanosoma cruzi*-like trypanosomatids, parasitological examinations were carried out by direct microscopic observation. For this, fresh fecal samples were obtained by abdominal compression of live triatomines, and the presence of flagellate forms was verified under an optical microscope at 400× magnification. Although direct microscopy may present limitations due to possible false positives caused by other flagellated protozoa, this method has been historically employed for routine surveillance due to its practicality and low cost. In this study, no molecular methods (*e.g.*, PCR) were applied to confirm positive results; thus, the infection rates reported should be interpreted with this limitation in mind.

Conservation and storage of triatomines

After taxonomic identification and parasitological examination, triatomine specimens that arrived in good condition were examined and subsequently deposited in the entomological collection of the Parasitology Laboratory at LACEN-SE. Those specimens that were not in good condition were discarded following the biosafety protocols of LACEN-SE.

Spatial Analysis

The geographic database was structured based on information related to the identified triatomine species, the number of specimens collected, and the natural infection by *Trypanosoma cruzi*-like trypanosomatids in 51 municipalities of the state of Sergipe from 2005 to 2023. Based on these data, thematic maps were developed to identify the spatial distribution patterns of triatomines across the state during the analyzed period. The thematic maps were created using QGIS 3.28 software (QGIS Development Team; Open Source Geospatial Foundation Project).

Entomological indices and Statistical Analysis

The following entomological indicators were considered: number of triatomines collected in the municipalities; density index (number of triatomines collected/number of households examined); dispersion index [(number of intradomiciliary and peridomiciliary sites/number of households examined) x 100]; intradomiciliary infestation index [(number of intradomiciliary sites with triatomines/number of households examined) x 100];

peridomiciliary infestation index [(number of peridomiciliary sites with triatomines/ number of households examined) x 100]; colonization index [(number of intradomiciliary sites with nymphs/number of households with triatomines) x 100]; natural infection index [(number of infected triatomines/number of examined triatomines) x 100]. the indicators were calculated according to the Pan American Health Organization (OPAS 2014).

The data were organized using Microsoft Office Excel® 2016 and analyzed with BioEstat v.5.3 and Statistica v.7.1 software. Absolute and relative frequencies of the collected triatomine data were calculated. The Mann-Whitney test was applied to compare different triatomine species collected in intradomiciliary and peridomiciliary environments. To assess the relationship between the number of triatomines collected and the number of reported households over the years, a simple linear regression analysis was performed, considering the number of reported households as the independent variable and the number of triatomines collected as the dependent variable. This analysis aimed to verify whether there was a trend of increase or decrease in the number of triatomines captured according to the number of households reported in each year of the study period. A significance level of 5% was adopted for all statistical analyses.

Ethical Aspects

The study used information on public access, with no participation of humans or animals.

Results

Table 1. Triatomines collected and *Trypanosoma cruzi* infection rate by collection site in the state of Sergipe, 2005–2023. / **Tabla 1.** Triatominos recolectados y tasa de infección por *Trypanosoma cruzi* según el sitio de recolección en el estado de Sergipe, 2005-2023.

Species	Intradomiciliary	Peridomiciliary	Total	Examined	p-value*	Infection	Infection rate
T. pseudomaculata	709	320	1,029	1,022	0.002	88	8.6
T. brasiliensis	367	70	437	433	<0.001	37	8.5
P. tibiamaculatus	83	5	88	88	<0.001	19	21.6
T. melanocephala	45	5	50	49	0.003	6	12.2
P. megistus	186	81	267	267	0.102	11	4.1
P. geniculatus	13	1	14	14	0.023	7	50.0
P. lutzi	581	22	603	603	<0.001	109	18.1
R. neglectus	4	0	4	4	0.202	1	25.0
R. domesticus	1	0	1	1	0.390	1	100.0
Rhodnius spp.†	4	1	5	5	0.385	3	60.0
Total	**1,993**	**505**	**2,498**	**2,486**	**-**	**282**	**-**

†Species identified only at the genus level.
*p-value: Significance of the comparison between different species of triatomines collected in indoor and peridomiciliary environments using the Mann-Whitney test.

According to data provided by LACEN-SE, between 2005 and 2023, a total of 2,498 triatomines were collected, with 67.9% (1,696) found in the intradomiciliary environment and 32.1% (802) in the peridomiciliary environment of the 1,353 investigated housing units.

Of the total specimens, 86.7% (2,166) were adults, while 13.3% (332) were nymphs. The most frequently collected species were *T. pseudomaculata* (41.2% - 1,029), *P. lutzi* (24.1% - 603), *T. brasiliensis* (17.5% - 437), and *P. megistus* (10.7% - 267).

A statistically significant difference was observed between species collected in intradomiciliary and peridomiciliary environments. *T. pseudomaculata*, *T. melanocephala*, *P. tibiamaculatus*, *P. geniculatus*, and *P. lutzi* were more frequently reported in the intradomiciliary environment, whereas *T. brasiliensis* was predominantly reported in the peridomiciliary environment over the 19-year study period (Tab. 1).

A total of 1,353 housing units were surveyed between 2005 and 2023, of which 88.9% were infested with triatomines. However, an annual decline of 13.4912 triatomines was observed in the number of kissing bugs collected in households ($r^2 = 0.6859$; $p < 0.001$) (Fig. 2). Regarding the number of triatomines collected, fluctuations were observed, with 2009 being the year with the highest number of specimens collected (300/2,498) and 2023 showing the lowest records (30/2,498).

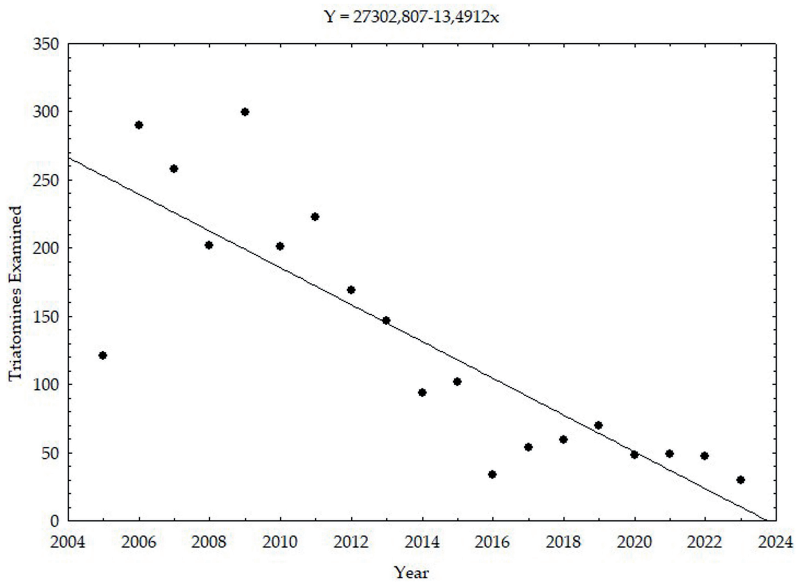


Figure 2. Linear regression between the number of investigated households and the total number of reported triatomines in Sergipe, Brazil, from 2005 to 2023, showing the direct relationship between inspected residences and collected vector insects. / **Figura 2.** Regresión lineal entre el número de viviendas investigadas y el total de triatominos notificados en Sergipe, Brasil, entre 2005 y 2023, mostrando la relación directa entre las residencias inspeccionadas y los insectos vectores recolectados.

The triatomines were reported in 51 out of the 75 municipalities in the state, with *T. pseudomaculata* being the most frequent species (64.7% - 33/51). The highest reports for this species occurred in Canindé de São Francisco with 26.0% (267/1,029); Poço Redondo with 13.7% (141/1,029); Porto da Folha with 11.9% (122/1,029), municipalities located in the semi-arid region of Sergipe, and Tobias Barreto with 18.1% (186/1,029), located in the agreste region of the state.

Panstrongylus lutzi was reported in 31 municipalities throughout the study (60.8%), with the highest occurrences in Tobias Barreto (256/603 - 42.5%) and Itabaianinha (66/603 - 11.0%). *Panstrongylus tibiamaculatus* was reported in 28 out of the 51 municipalities (54.9%), showing a heterogeneous distribution in the notified areas.

Triatoma brasiliensis was reported in 19 municipalities (37.3%), with Canindé do São Francisco (201/437 - 46.0%), Porto da Folha (104/437 - 23.8%), and Poço Redondo (76/437 - 17.4%) showing the highest notifications over the 19 years of study. *Panstrongylus megistus* was reported in 15 municipalities (29.4%), with the highest notification occurring in Itabaianinha, accounting for 63.7% (170/267) (Fig. 3).

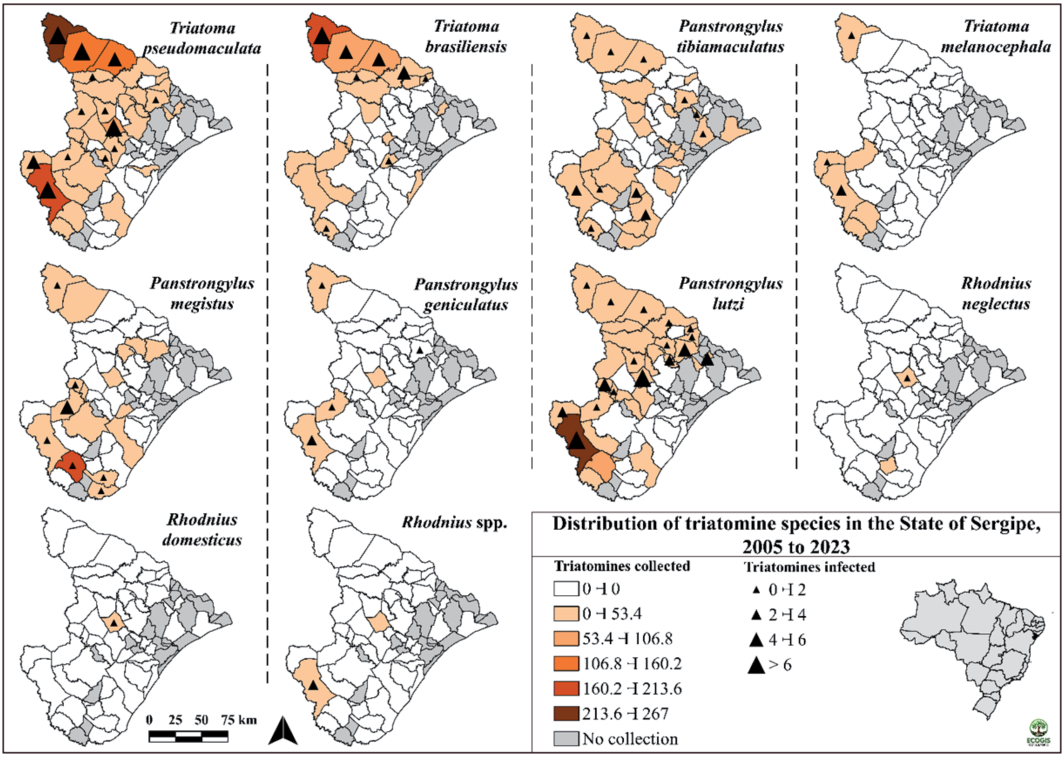


Figure 3. Geographic distribution of triatomine species and *Trypanosoma cruzi*-like infection by municipality, Sergipe, Brazil, 2005 to 2023. / **Figura 3.** Distribución geográfica de las especies de triatominos y de la infección similar a *Trypanosoma cruzi* por municipio, Sergipe, Brasil, de 2005 a 2023.

The recorded density index for all years was 1.9%, with the highest density index observed in 2006 (2.4%) and the lowest in 2019 (1.2%). The calculated dispersion index for all years was 3.6%, with 2023 presenting the highest index of the period (17.7%). Comparing intradomiciliary and peridomiciliary infestation indicators, both showed fluctuations over the years, with intradomiciliary infestation reaching 88.9% and peridomiciliary infestation at 14.6%. In the years 2014, 2016, 2019, 2022, and 2023, the intradomiciliary infestation index reached 100% (Fig. 4). The colonization index throughout the study period was 6.1%, with 2006 standing out as the year with the highest colonization index (15.1%) among all years analyzed.

The natural infection rate during the study period was 11.3% (282/2,498). Infection rates fluctuated over the years, with 2007 recording the highest rate at 18.8%. Among the collected species, *P. lutzi* had the highest number of infected specimens (109/282), with a natural infection rate for *Trypanosoma cruzi*-like trypanosomatids of 18.1%, followed by *T. pseudomaculata* (8.6% - 88/282) and *T. brasiliensis* (8.5% - 37/282) (Tab. 1) (Fig. 3).

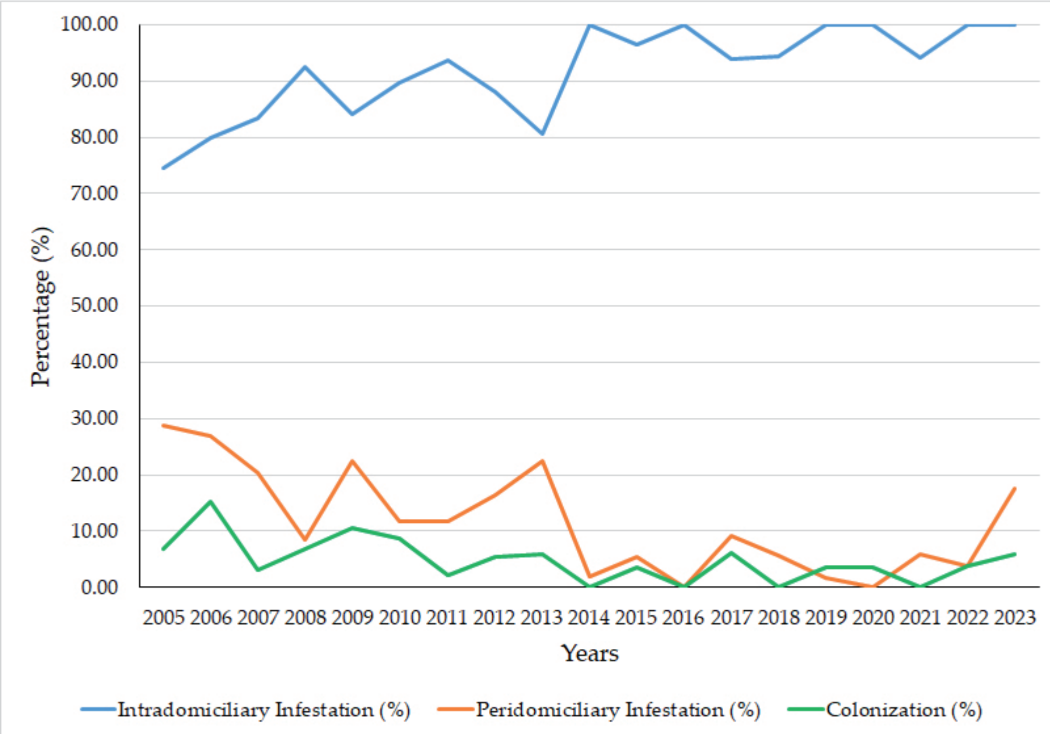


Figure 4. Entomological indicators of intradomiciliary and peridomiciliary infestation and colonization of triatomines collected in Sergipe, Brazil, from 2005 to 2023. The graph shows the annual infestation rates in indoor and surrounding areas of households, as well as the colonization percentage identified by the presence of nymphs. / **Figura 4.** El gráfico muestra las tasas anuales de infestación en ambientes internos y en los alrededores de las viviendas, así como el porcentaje de colonización identificado por la presencia de ninfas.

Discussion

The major challenge in controlling Chagas disease in the Northeast region of Brazil has been understanding the epidemiological and entomological dynamics of the disease and its vectors. This study demonstrated that entomological surveillance activities, which are the foundation of vector control, have shown significant fluctuations over the years in municipalities across the state of Sergipe. These variations raise concerns, particularly regarding the underreporting of Chagas disease cases. The passive surveillance activities conducted in Sergipe over the 19-year study period revealed the presence of triatomine species characteristic of the Northeast region of Brazil, such as *T. pseudomaculata*, *T. brasiliensis*, *P. lutzi*, and *P. megistus*.

The data on the species found are in accordance with previously documented records from other states in the Northeast, reinforcing the endemicity of these species in the region (Gurgel-Gonçalves *et al*. 2012; Silva *et al*. 2012; Barbosa-Silva *et al*. 2016; Lilioso *et al*. 2017; Melo *et al*. 2018; Galvão *et al*. 2024). The high prevalence of *T. pseudomaculata* and *T. brasiliensis* can be explained by the fact that the Caatinga biome, which dominates the study area, likely represents the epicenter of their dispersal (Galvão and Justi 2015).

This study identified *T. pseudomaculata*, *T. melanocephala*, *P. tibiamaculatus*, *P. geniculatus*, and *P. lutzi* as the primary vector species found in intradomiciliary environments in municipalities across Sergipe. Although these species exhibit different habitat preferences, their presence inside homes can be attributed to multiple factors (Forattini 1980). Their intrusion into human dwellings may result from habitat loss due to anthropogenic activities such as deforestation or attraction to artificial light sources (Walter *et al*. 2005; Assis *et al*. 2007; Bernardo-Pedro *et al*. 2019). The destruction of natural habitats forces animals — particularly mammals that serve as food sources for triatomines — to move closer to human dwellings. This increases the likelihood of vector invasion and colonization, making both humans and domestic animals more vulnerable to *T. cruzi* infection (Borges *et al*. 2005; Assis *et al*. 2007).

The presence of *T. brasiliensis* in the peridomestic environment, originally a wild species, results from its ability to adapt to human-modified environments. This highly generalist species, with a diverse diet, is capable of feeding on a variety of vertebrates, including mammals, birds, and reptiles, which facilitates its colonization in peripheral areas of households, where domestic and farm animals are also found (Silveira *et al*. 2011; Coutinho *et al*. 2014; Lilioso *et al*. 2020). Therefore, the presence of *T. brasiliensis* in the peridomestic environment is closely linked to its ecological plasticity and opportunistic feeding behavior, factors that favor its colonization in modified environments and its role as a disease vector (Sarquis *et al*. 2012). It is noteworthy that Canindé de São Francisco, a municipality that reported a high number of triatomine notifications during the study period, is an important tourist destination in the state of Sergipe, attracting visitors from various regions of Brazil and abroad throughout the year. This condition underscores the importance of maintaining and strengthening vector surveillance in tourist areas as a fundamental measure for protecting public health and ensuring the sustainability of local tourism activities. The presence of triatomines in areas with a high influx of tourists increases the risk of exposure of non-residents to *Trypanosoma cruzi*, including visitors who are often unaware of the risks associated with Chagas disease and may not recognize the vectors or their characteristics. Additionally, the detection of triatomines in tourist areas can negatively impact visitors' perception of sanitary safety, economically affecting communities that rely on tourism as a source of income. There is also the potential for the parasite to disperse to other regions of the country, considering that infected tourists may remain asymptomatic for extended periods.

In this context, Faúndez and Carvajal (2012) emphasize the importance of including tourist areas in the planning of entomological surveillance strategies, while Pires-Silva *et al*. (2025) highlight that surveillance in territories with high tourist flows is essential for preventing new cases of vector-borne transmission of Chagas disease. Therefore, it is necessary to integrate entomological surveillance actions in these territories, including health education initiatives aimed at tourists and tourism sector workers, regular inspections of lodging facilities and tourist attractions, as well as environmental control strategies and monitoring of synanthropic fauna, with the goal of preventing the transmission of *T. cruzi* and ensuring the safe continuation of tourism activities in endemic areas.

The progressive reduction in the number of triatomines collected over the 19 years analyzed may be related to control measures implemented during this period, such as chemical control, health education programs, and the Housing Improvement Program for Chagas Disease Control (Gurgel-Gonçalves *et al*. 2012). However, it is important to highlight that the continuity of these vector control actions was not consistent over time. Additionally, the decentralization of health services may have impacted surveillance in the state, influencing the observed results.

Regarding the year 2009, this peak may be associated with the decentralization of the Chagas Disease Control Program, when the responsibility for implementing control actions shifted from the Superintendence of Public Health Campaigns to state and municipal governments (Ferreira *et al*. 2006). This change may have led to discontinuities in the control program, lack of resources, or difficulties in local organization, negatively affecting the surveillance and control of triatomines. As a consequence, areas that were previously monitored on a regular basis began to report higher numbers of captured insects, reflecting a reduction in the effectiveness of surveillance and control actions during the transition period between levels of government. (Ferreira *et al*. 2006). At the same time, recent years have been marked by multiple arbovirus epidemics in the country, such as Dengue, Chikungunya, and Zika, as well as the official declaration in 2006 of the interruption of vector transmission of Chagas disease by *Triatoma infestans* (Klug, 1834). This contributed to the false belief that Chagas disease had been eliminated in Brazil (Silveira *et al*. 2011; Dias *et al*. 2016). These factors may have negatively impacted entomological surveillance activities, mainly due to local management issues and the reallocation of resources to combat arboviruses, disproportionately affecting less densely populated rural areas in northeastern Brazil (Dias *et al*. 2016). On the other hand, the sharp decline in the number of triatomines collected from 2013 onward should be interpreted with caution due to the possibility of underreporting, given that Chagas disease is a neglected disease. This possibility reinforces the need for more rigorous entomological surveillance to confirm whether there has indeed been a real decrease in the blood-sucking triatomine population (Dias *et al*. 2000). The decline in triatomine captures observed after 2013, attributed in this study to possible underreporting, may be related to institutional factors that directly impact entomological surveillance, such as the reduction in the number of field agents, often resulting from funding cuts and the prioritization of other endemic diseases. This scenario compromises systematic household visits, active searches, and monitoring of residual foci, resulting in lower detection and reporting of triatomines (Dias *et al*. 2000).

Additionally, institutional changes, including restructurings within health departments, the integration of surveillance programs, or alterations in reporting workflows, may have led to discontinuities in control activities and inconsistencies in information systems, affecting the quality of the available data (Cerqueira *et al*. 2003; Silveira and Pimenta-Junior, 2011; Sampaio *et al*. 2023). Thus, the marked decline in the number of collected triatomines should be interpreted with caution, considering the context of underreporting and the historical neglect of Chagas disease in Brazil, reinforcing the importance of rigorous entomological surveillance to confirm whether the reduction reflects a true decrease in vector populations (Dias *et al*. 2000). In this context, programs such as the Housing Improvement Program for the Control of Chagas Disease (MHCDCh) become even more relevant by prioritizing municipalities with greater vulnerability to vector-borne transmission, using data from the Brazilian Ministry of Health to support structural interventions aimed at reducing household and peridomestic infestation (Melo *et al*. 2018). In the state of Sergipe, information on triatomine presence enabled the allocation of approximately USD 670,000 for the renovation and reconstruction of housing in eight eligible municipalities, with these benefits expected to be enhanced by hygiene and environmental management actions. These initiatives contribute to strengthening entomological surveillance, reducing underreporting gaps, and ensuring the continuity of Chagas disease control actions in an integrated and sustainable manner (Melo *et al*. 2018).

Regarding the spatial distribution of species in Sergipe, *T. pseudomaculata* was the most frequently reported (33/51), with a higher concentration in municipalities of the semi-arid region of the state. *T. pseudomaculata* is an autochthonous species, ecologically adapted to the Caatinga biome, and plays a significant role in the domiciliation process in the Northeast of Brazil. It ranks second in the number of collections in intradomiciliary environments and is an important vector of Chagas disease in the region, with confirmed presence in all northeastern states (Galvão *et al*. 2024). In contrast, some species recorded in this study, such as *P. geniculatus* and *R. neglectus*, are not considered native to Sergipe, suggesting sporadic introductions or passive dispersal events. This distinction reinforces the relevance of *T. pseudomaculata* in local transmission dynamics and highlights the need for sustained entomological surveillance in areas where it is prevalent.

Panstrongylus lutzi was the second most frequently reported triatomine species in the state of Sergipe. Predominantly a sylvatic species, it can also be found in intradomiciliary and peridomiciliary environments, particularly in its adult stage. It is notable for its high invasion capacity, mainly due to its flight ability, and generally exhibits a high natural infection rate. In Brazil, its distribution includes the states of Alagoas, Bahia, Ceará, Minas Gerais, Paraíba, Pernambuco, Piauí, Rio Grande do Norte, and Sergipe (Galvão *et al*. 2024). In its natural environment, *P. lutzi* inhabits rocky areas and is frequently associated with armadillo burrows (Galvão *et al*. 2024).

Panstrongylus tibiamaculatus showed the greatest spatial heterogeneity among the recorded species; *it* is a wild species predominantly found in the Atlantic Forest biome; however, in Sergipe, it has also been recorded in the Caatinga biome (Candido *et al*. 2019). This species has low vectorial capacity (Galvão *et al*. 2024).

Triatoma brasiliensis is considered the most important vector since the elimination of *T. infestans*, exhibiting high infection levels and being highly generalist in both feeding habits and habitat. It can be found in intradomiciliary, peridomiciliary, and wild environments (Fontes *et al*. 2024). In this study, *T. brasiliensis* was more frequently found in the semi-arid region of Sergipe. This species is characteristic of the region and naturally inhabits the crevices of rocky outcrops in the semi-arid landscape, where it develops colonies associated with wild rodents of the species *Kerodon rupestris* (Wied-Neuwied, 1820) (Rodentia: Caviidae), a mammal with high *T. cruzi* infection rates (Fontes *et al*. 2024). The analysis of entomological indicators of Chagas disease in the state of Sergipe between 2005 and 2023 reveals significant fluctuations in domestic and peridomestic infestation rates, with the highest triatomine density recorded in 2006 (2.4%) and the lowest in 2019 (1.2%). Although domestic infestation remained predominantly high (88.9%) throughout the period, with peaks of 100% in specific years such as 2014, 2016, 2019, 2022, and 2023, peridomestic infestation remained significantly lower (14.6%).

The increase in dispersion observed in 2023 (17.7%) and the colonization rate of 6.1% over the study period suggest that, despite control campaigns, persistent triatomine foci still exist, indicating that the vector continues to pose a transmission risk for Chagas disease, particularly in rural areas (Dias *et al*. 2000). The data suggest that while control measures have been effective in reducing infestation rates, vector dynamics remain influenced by environmental factors (Sarquis *et al*. 2012). The domestic environment, due to the availability of food sources and suitable shelters for triatomines, remains the primary site of infestation, whereas the peridomestic area, though less affected, still serves as a refuge and reintroduction zone for the vector (Lilioso *et al*. 2017; Melo *et al*. 2018).

The increase in dispersion and fluctuations in infestation rates highlight the need for continuous and integrated control, involving not only insecticide application but also health education, housing improvements, and proper management of the peridomestic environment to prevent the reintroduction of the disease in previously controlled areas (Candido *et al*. 2019).

Regarding the natural infection rate of triatomines by *Trypanosoma cruzi*, the infection rate of 11.3% among collected triatomines is concerning, particularly in species such as *P. lutzi* (18.1%) and *T. pseudomaculata* (8.6%). The feeding versatility of these species and the high capacity of *P. lutzi* to invade domestic environments increase the risk of human infection by *T. cruzi* (Candido *et al*. 2019). *Triatoma brasiliensis* also showed high representation, being considered the primary vector of *T. cruzi* transmission in the Northeast region of Brazil, with a high degree of synanthropy (Sarquis *et al*. 2012).

Regarding the natural infection rate of triatomines by *Trypanosoma cruzi*, an infection rate of 11.3% was observed among the collected triatomines, with *P. lutzi* (18.1%) and *T. pseudomaculata* (8.6%) standing out. The feeding versatility of these species and the high capacity of *P. lutzi* to invade domestic environments increase the risk of human infection by *T. cruzi* (Candido *et al*. 2019). *Triatoma brasiliensis* also showed high representativeness, being considered the main vector of *T. cruzi* transmission in the Northeast region of Brazil, with a high degree of synanthropy (Sarquis *et al*. 2012).

Conclusions

Finally, the presented data underline the complexity of controlling Chagas disease in Sergipe. The geographical distribution of triatomine species and the variation in infection rates by municipality indicate that control strategies should be adapted to local conditions. Moreover, the high rate of domestic infestation highlights the vulnerability of rural and peri-urban populations, which remain exposed to these vectors. Therefore, health education programs, combined with vector control measures, should be intensified to reduce triatomine presence and prevent the transmission of Chagas disease.

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Author Contributions

CMM: Conceptualization, methodology, investigation, writing – review & editing, visualization, supervision, project administration, funding acquisition. **FMF, NAFS:** Conceptualization, methodology, formal analysis, investigation, data curation, writing – original draft, writing – review & editing, visualization. **VLSJ:** Data curation, writing – review & editing. **RESJ:** Methodology, writing & editing. **JO:** Writing – review & editing. **RSG and KDM:** Data curation. **RRM:** Conceptualization, methodology, data curation, weiting – review & editing. **JAR:** Data curation, writing – review & editing.

Conflict of Interest

The authors declare that there is no conflict of interest.

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