

Spatial distribution of synanthropic triatomines in Piauí State, Northeastern Brazil

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ABSTRACT

This study aimed to describe the spatial distribution and assess entomological indicators of synanthropic triatomines in Piauí State, Northeastern Brazil. We used surveillance data on the detection, identification and assessment of natural infection with trypanosomatids from triatomines in the State from 2014 to 2017. The State was divided into four macroregions. In relation to the dispersion rates of triatomines, they were much lower in the North, when compared to Southwest, Southeast and Central North macroregions. Infestation rates were higher in the Southwest and Southeast and intradomicile infestation rates varied during the study period, reaching high values in all regions. Insects belonging to the species *Triatoma brasiliensis* complex, *Triatoma pseudomaculata*, *Triatoma sordida*, and to the genus *Panstrongylus* spp. and *Rhodnius* spp. were collected during this period. *T. brasiliensis* was collected from all four regions of the State, but more frequently in those located in the Southeast. A similar pattern was observed for *T. pseudomaculata*. *T. sordida* was detected in the municipalities in the Southeast and Southwest regions, and less frequently in the Central North municipalities. *Rhodnius* spp. was detected in the Central North and North regions, and *Panstrongylus* spp. in the Central North and Southeast regions. The highest trypanosomatid-positivity rate of *T. brasiliensis* and *Panstrongylus* spp. was in the Southeast region. A significant proportion of the municipalities of Piauí State presents entomological parameters that indicate a risk of Chagas disease by vector transmission.

KEYWORDS: Chagas disease. Spatial distribution. Triatomines. Piauí State.

INTRODUCTION

Chagas disease (American trypanosomiasis) is caused by the protozoan *Trypanosoma cruzi*. This organism circulates enzootically in nature, transmitted among sylvatic and domestic mammals by hematophagous insects of the subfamily Triatominae¹. When triatomines feed on humans they can transmit *T. cruzi*, which is shed in their feces shortly after bloodsucking. The various species of triatomines occupy specific geographic distributions, defined in part by their natural habitats within different regions and biomes on the American continent²⁻⁷. Distinct species of triatomines transmit *T. cruzi* with varying efficiency, defined by the insects' behavior, physiology and adaptation to the human domicile⁸⁻¹¹. After an intensive utilization of pyrethroid insecticides in endemic areas in Brazil, the transmission of Chagas disease by triatomines (mainly *Triatoma infestans*) was virtually eliminated in many States¹². In 2006, Brazil received the Certificate of Interruption of Transmission of Chagas Disease by *Triatoma infestans* by the Pan American Health Organization/

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World Health Organization¹³. This was possible due to the virtual inexistence of wild stocks of *T. infestans*, which was introduced in Brazil (non-autochthonous) and, consequently, was restricted to domestic and peridomestic environments^{14,15}. Nevertheless, this is not the situation of Northeastern Brazil, where surveillance activities need to be maintained after control efforts, since *T. cruzi* transmitters are native and consequently have wild environments as their natural habitat¹⁶. The region presents a worrying situation because it contains the highest prevalence of secondary vectors involved in the transmission of the disease. In particular, it contains the dispersion epicenter of two species that are difficult to control by the routine methods recommended by the National Health Foundation, *Triatoma brasiliensis* and *Triatoma pseudomaculata*. Here, a high proportion of the rural population lives in precarious housing conditions and there is a low level of operational coverage in the Chagas disease control program¹⁷.

Studies of Chagas disease in Piauí State began in 1916, with the identification of individuals presenting with megaesophagus and heart disease, in addition to the occurrence of four species of triatomines in the municipalities of São Raimundo Nonato, Parnaíba and Corrente¹⁸. In 1975, the first autochthonous cases of Chagas disease with cardiac and digestive manifestations were reported in the municipalities of Oeiras, Castelo do Piauí and Bom Jesus do Gurueia¹⁹. Data from the first national Chagas disease serological survey, performed between 1975 and 1980, showed that Piauí was among the six Brazilian States with a global seroprevalence rate of Chagas disease above 4%, with involvement of all age groups²⁰. In the same period, it was demonstrated that the municipality of Oeiras was considered an area of active transmission due to the presence of domiciliary triatomines infected with *T. cruzi*, and children under 5 years old presenting positive serology for the disease²¹. In addition to this study, several others were carried out showing both, the distribution and the seropositivity of triatomines in the State²²⁻²⁶.

Between 1996 and 1997, in conjunction with active control programs, a serological survey with school-aged children registered a significantly lower prevalence rate and pointed to a substantial decrease in transmission²⁷. In 2002, a new State-based serological survey was carried out, including 36,399 people living in rural areas across 216 municipalities. This study, which estimated a prevalence rate of 1.9%, ranging from 0.1% in children under 4 years of age to 6.5% in people aged 60 to 69 years, demonstrated the heterogeneity of the spatial distribution of the disease in Piauí State. In this way, the municipalities belonging to the health districts based in Oeiras, São João do Piauí and Picos had the highest positivity rates, ranging from 4.3% to

5.3%²⁸. These regions are located in the Caatinga biome of the semiarid region in the Southeast of the state. This work aimed to describe the current spatial distribution and assess entomological indicators of vectors of *Trypanosoma cruzi* infection in Piauí State, through the collection of the most recent data generated by the entomological surveillance system of the State.

MATERIAL AND METHODS

Description of the study area

The Piauí State is located between 2°44'49'' and 10°55'05' South and between 40°22'12'' and 45°59' West. According to IBGE²⁹, the State has an estimated population of 3,273,227 people, occupying an area of 251,529 km², divided into 224 municipalities and bounded by the states of Ceará and Pernambuco to the East, Bahia to the South and Southeast, Tocantins to the Southwest and Maranhão to the West. It presents a typical tropical climate with high average temperatures ranging from 18 °C to 39 °C and relative humidity ranging from 60% to 86%. The State is divided into four main regions: North, Central North, Southwest and Southeast (Figure 1). The Piauí State presents a confluence of three Brazilian biomes. In the East and Southeast of the State, semi-arid landscapes predominate in the Caatinga biome and, in the Southwest, the Cerrado vegetation predominates. To the West, along the border with the State of Maranhão, an extensive ecotonal area is represented by the Mata de Cocais, where palm trees of different species abound^{30,31}.

Entomological surveillance

Currently, the control of Chagas disease has been guided by entomological surveillance actions and focal interventions with insecticides. Active surveillance is coordinated by agents in a decentralized manner, managed by the municipal administration under the supervision of the State Health Secretariat. Surveillance information is centralized in a database called the Field Operations Information System - Chagas/Piauí. In the field, surveillance actions involve home visits in which houses are inspected in detail by insect-seeking agents, both inside the dwellings and peridomestic structures, such as pens, poultry houses and backyards. In the Piauí State, the captured insects are sent to a laboratory and identified at the species level, in addition to having their intestinal contents examined by light microscopy to evaluate the presence of flagellate protozoa (trypanosomatids). For the present study, specimens belonging to different species of the genera *Panstrongylus* spp. and *Rhodnius* spp. were grouped within the respective

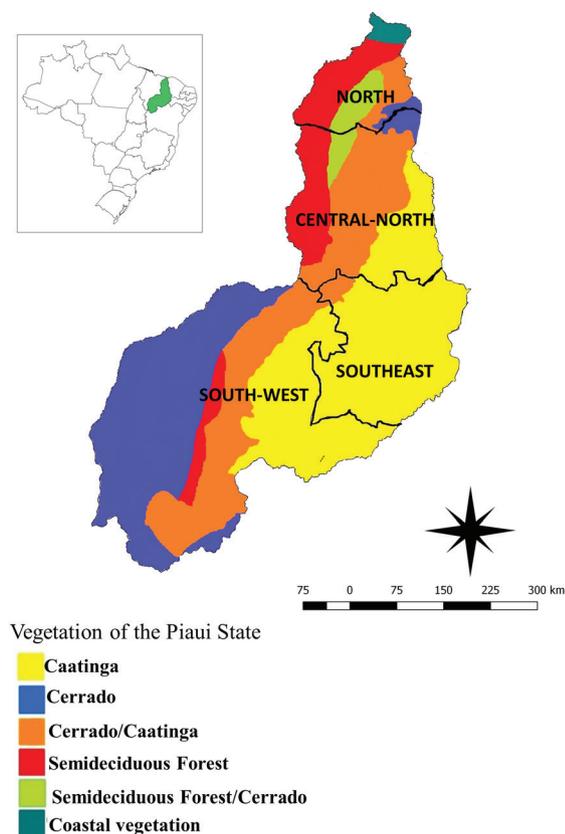


Figure 1 - Map of Piauí State with the division of regions and type of vegetation.

genera due to the possibility of misidentifications at the species level by the local entomological surveillance technicians. This strategy was chosen after preanalytical procedures have identified some inconsistencies in the database, with the presence of *Panstrongylus* spp. and *Rhodnius* spp. species not yet described in the state. Thus, as these specimens were no longer available for reidentification by specialists, it was decided to consider only the genus.

Each municipality can choose whether or not to carry out the entomological surveillance activities of Chagas disease, and the municipality can also establish the coverage of activities in its territory. In this way, some municipalities did not carry out surveillance and therefore did not provide data for the system.

Ecological and geospatial analysis

We used the entomological monitoring data that includes information on capture, identification and assessment of natural infections with trypanosomatids of triatomines in the 224 municipalities in Piauí State during the period 2014 to 2017. The following variables for each municipality were assessed: (i) State region (categorized as North [n=32

municipalities], Central North [n=64], Southeast [n=66] and Southwest [n=62]), (ii) presence of *T. brasiliensis*, *T. pseudomaculata*, *T. sordida*, *Panstrongylus* spp., and/or *Rhodnius* spp., (iii) rate of entomological surveillance coverage (number of locations evaluated/ total locations $\times 100$), (iv) rate of dispersion (number of localities with triatomines/ total evaluated localities $\times 100$), (v) rate of infestation (number of houses with triatomines/total houses evaluated $\times 100$), (vi) rate of intradomiciliary infestation³² (number of households with intradomiciliary insects/ total houses evaluated $\times 100$), (vii) absolute number of adult insects of each species collected in the intradomicile and the peridomicile, (viii) absolute number of nymphal instar insects of each species collected in the intradomicile and the peridomicile, (ix) number of trypanosomatid-infected triatomines (number of triatomines infected by trypanosomatids of each species collected in the intradomicile and the peridomicile), and (x) rate of natural infection by trypanosomatids (number of positive triatomines/ total triatomines examined $\times 100$). The analytical strategy was to compare the entomological indicators from each year in the four regions of the State, seeking differences in the spatial distribution of the various vector species of *Trypanosoma cruzi* infection. The data were made available by the municipalities. From these, thematic maps were prepared with the rates of surveillance coverage, dispersion rate, infestation rate and colonization rate, for each year of the historical series. Analyzing the number of insects and the number of infected insects, the centroids of each municipality with surveillance activities were used to plot pie charts with insect counts for each municipality and, through a Kernel (Bipedal quarry with radius 30,000 units of the layer) function, calculate the hot areas for each vector in the Piauí State, over the range of years of the study. The QGIS software was used for the analyzes, with the Coordinate Reference System EPSG: 4326 - WGS 84. The cartographic bases were obtained from the Brazilian Institute of Geography and Statistics.

RESULTS

Entomological indicators of vectors of *Trypanosoma cruzi* infection in Piauí State, 2014 – 2017

Among the 224 municipalities in Piauí State, the proportion that registered surveillance activities in some year between 2014 and 2017 was 10/32 [31.3%] in the North, 23/64 [35.9%] in the Central North, 61/66 [92.4%] in the Southeast and 43/62 [69.4%] in the Southwest regions. The spatial variation of the entomological indicators in the State from 2014 to 2017 can be seen in [Figure 2](#) and

Table 1. Regarding the coverage of surveillance actions of the vectors of Chagas disease, it can be observed that the highest rates are those of the municipalities of the Central North, Southeast and Southwest regions along the borders with the states of Ceara, Pernambuco and Bahia, in an area located in the East of the State. In relation to the dispersion rates of triatomines, they were much lower in the North, when compared to Southwest, Southeast and Central North regions. Infestation rates were higher in the Southwest and

Southeast and intradomicile infestation rates varied during the study period, reaching high values in all regions.

Spatial distribution of distinct vector species of *Trypanosoma cruzi* infection in Piauí State, 2014 – 2017

Insects belonging to the species *T. brasiliensis* complex, *T. pseudomaculata*, *T. sordida*, *Panstrongylus* spp. and

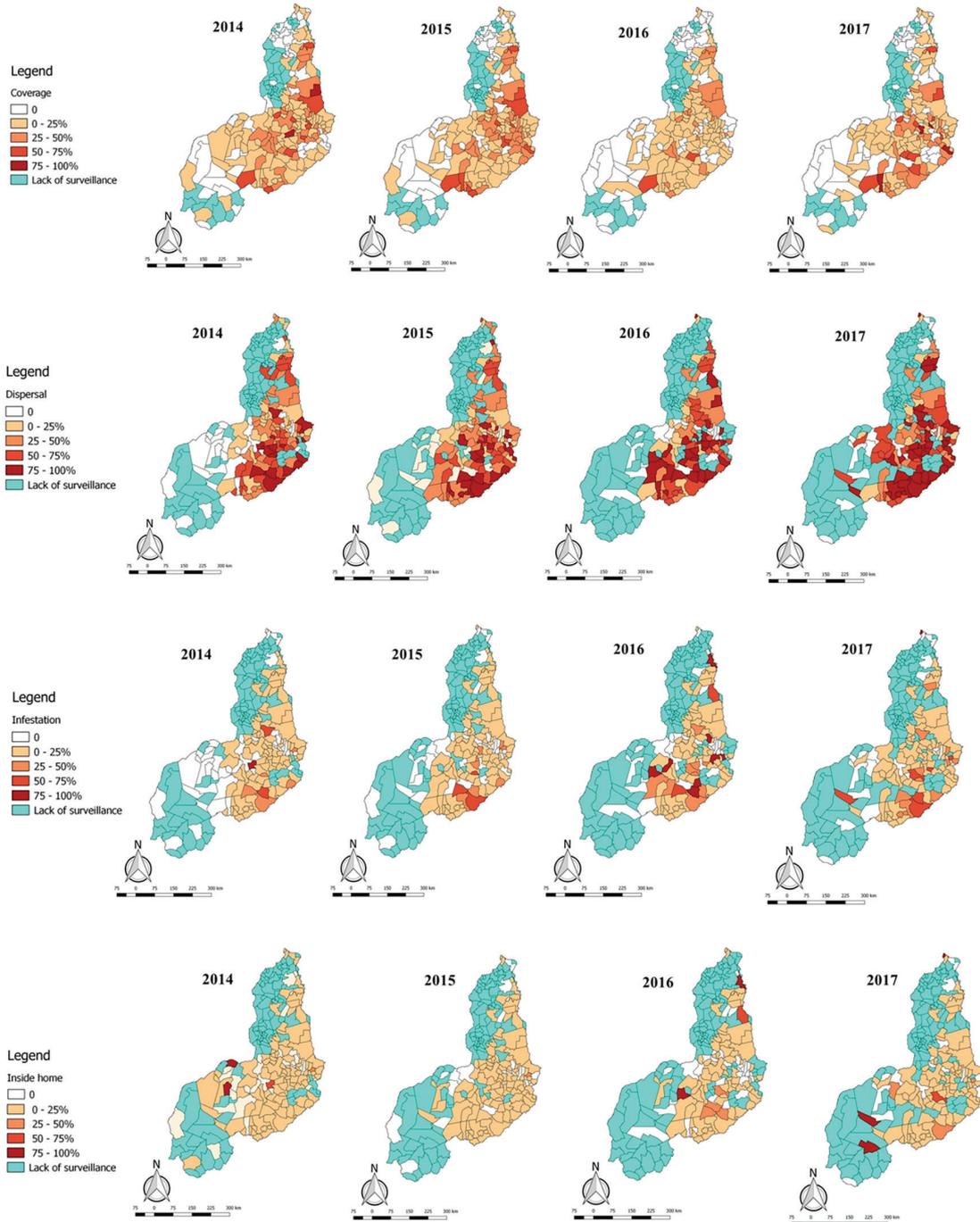


Figure 2 - Spatial variation of the entomological indicators in Piauí State in the years 2014 to 2017.

Table 1 - Entomological indicators of Chagas disease vectors in the Piauí State, 2014 – 2017.

Year/Region	Mean ± SD (range) of coverage rates in the municipalities, expressed in % ¹	Mean ± SD (range) of dispersal rates in the municipalities, expressed in % ²	Mean ± SD (range) of infestation rates in the municipalities, expressed in % ³	Mean ± SD (range) of intradomiciliary infestation rates in the municipalities, expressed in % ⁴
2014				
Central North	15.6 ± 31.2 (0-100)	14.5 ± 23.2 (0-83)	3.1 ± 7.8 (0-54)	2.3 ± 3.5 (0-12)
North	10 ± 24.8 (0-80)	6.1 ± 14.8 (0-66)	0.1 ± 0.3 (0-1)	0.4 ± 0.4 (0-1)
Southeast	48.2 ± 34.1 (0-100)	42.7 ± 32.9 (0-100)	8.6 ± 11.5 (0-54)	4.1 ± 5.8 (0-32)
Southwest	28.1 ± 34.4 (0-100)	14.6 ± 25.7 (0-100)	3.8 ± 13.6 (0-100)	6.6 ± 17.9 (0-100)
2015				
Central North	19 ± 35.3 (0-100)	13.3 ± 22.6 (0-100)	2.3 ± 4.5 (0-20)	2.1 ± 2.9 (0-9)
North	15.1 ± 33.2 (0-100)	9.1 ± 22.9 (0-100)	0.8 ± 2.4 (0-9)	2.4 ± 2.9 (0-6)
Southeast	42 ± 36.3 (0-100)	43.4 ± 33.3 (0-100)	10.1 ± 13.1 (0-62)	4.6 ± 6.3 (0-31)
Southwest	29.4 ± 39.4 (0-100)	18.3 ± 29.9 (0-100)	3.7 ± 9.6 (0-62)	3.6 ± 5.4 (0-24)
2016				
Central North	17.6 ± 35.7 (0-100)	16.7 ± 26.5 (0-100)	3.5 ± 8.8 (0-59)	4.1 ± 11.6 (0-59)
North	6.4 ± 24.9 (0-100)	6.4 ± 21.9 (0-100)	2.8 ± 13.9 (0-78)	21.3 ± 40.3 (0-92)
Southeast	19.4 ± 31.8 (0-100)	36.7 ± 39.5 (0-100)	11.6 ± 20.6 (0-100)	5.3 ± 9.7 (0-39)
Southwest	10.5 ± 24.4 (0-100)	17.6 ± 30.1 (0-100)	7.2 ± 19 (0-100)	7.9 ± 17.8 (0-92)
2017				
Central North	12.9 ± 30.8 (0-100)	14.1 ± 25.8 (-83)	2.6 ± 6.1 (0-31)	2.1 ± 2.6 (0-10)
North	3.2 ± 17.9 (0-98)	5.1 ± 18.7 (0-100)	0.2 ± 0.9 (0-5)	14.8 ± 33.6 (0-83)
Southeast	44 ± 41.1 (0-100)	51.6 ± 36.4 (0-100)	12.5 ± 15.4 (0-68)	6.1 ± 9.2 (0-55)
Southwest	12.8 ± 27.2 (0-100)	23.3 ± 32 (0-100)	6.5 ± 13.2 (0-70)	11.9 ± 24.3 (0-100)

The values represent the means ± standard deviations (SD) and the range of the rates, expressed in % in the municipalities belonging to each region of the state in the evaluated years: ¹number of locations evaluated in the municipality / total locations in the locality × 100; ²number of localities with triatomines / total evaluated localities × 100; ³number of houses with triatomines / total houses evaluated × 100; ⁴number of houses with intradomiciliary triatomines / total houses evaluated × 100.

Rhodnius spp. were collected. *T. brasiliensis* was collected in municipalities of all four regions of the State, but more frequently in those located in the Southeast (Figure 3). In this region, *T. brasiliensis* was present in 44%-73% of the municipalities during the study period. In the Central North and Southwest regions, the proportion of municipalities that were positive for *T. brasiliensis* ranged from 20% to 30%. A similar pattern was observed for *T. pseudomaculata*, which was identified in 40% to 50% of the municipalities in the Southeastern region of Piauí State between 2014 and 2017, and between 20% and 30% of the municipalities in the Central North and Southwest regions. A different pattern was identified for *T. sordida*, which was detected in 9% to 16% of the municipalities in the Southeast and Southwest regions in different years, and in less than 7% in the Central North municipalities. Also different was the geographic distribution of *Rhodnius* spp. detected from 2014 to 2017

in 7% to 15% of the Central North municipalities, up to 9% of the Northern municipalities, and was almost undetected in the Southeast and Southwest regions. *Panstrongylus* spp. was detected in the Central North regions (14% of municipalities in 2015) and Southeast (18% of municipalities in 2017). There is a heterogeneous geographic distribution of the different vector species of *Trypanosoma cruzi* infection in Piauí State (Figure 4). The predominance of *T. brasiliensis* can be observed in the North, Central North, Southeast and Southwest regions, whereas *T. sordida* is most frequently detected in the Central North, Southeast and Southwest regions. *T. pseudomaculata* and *Panstrongylus* spp. present hotspots in North, Central North, Southeast and Southwest regions. It may be noted that *Rhodnius* spp. was most frequently captured in the North and Central North regions. The mean number of specimens (including the developmental stage) collected

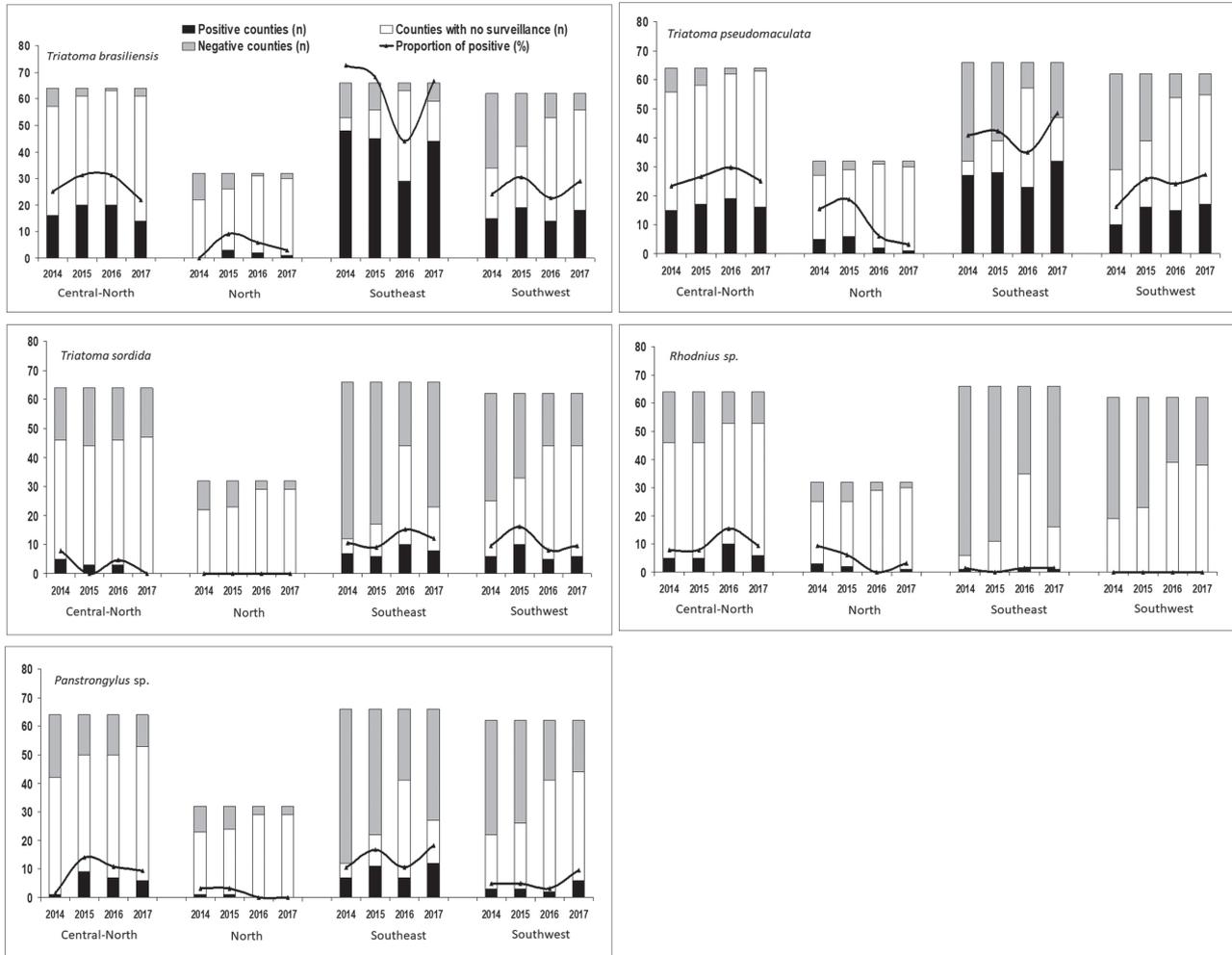


Figure 3 - Distribution of triatomines in Piauí State by species, year and region, during the period from 2014 to 2017.

in the different regions of the State in the period studied is shown in Table 2. The mean number of specimens of *T. brasiliensis* from the municipalities was higher in the Southeast region of the State, considering specimens of all stages and places of capture (adults inside houses, nymphs inside houses, adults in the peridomicile and nymphs in the peridomicile). For *T. pseudomaculata*, the Central North and Southwest regions had the highest mean numbers. *T. sordida* was captured far more frequently in the Southwest region of the State and *Rhodnius* spp., in the Central North followed by the North region. *Panstrongylus* spp. was collected more frequently in the Central North region.

Trypanosomatid infection rates in vectors of Chagas disease in the Piauí State

The geographic distribution of trypanosomatid-positive triatomines can be seen on the maps shown in (Figure 5). The occurrence of *T. brasiliensis* positive for trypanosomatids in the North, Central North, Southeast and Southwest

regions, with a higher proportion of positive insects captured in the Southeast, can be observed. *T. sordida* was more frequently captured in Southeast and Southwest regions, with a predominance of positive insects in the Southwest region. *T. pseudomaculata* was captured more frequently in the North, Central North, Southeast and Southwest regions, with a predominance of positive insects in the Central North region. Infected *Panstrongylus* spp. were frequently captured in the North, Central North, Southeast and Southwest regions, with the highest proportion recorded in the Southwest. It can be observed that infected *Rhodnius* spp. were more frequently captured in the North and Central North regions, with emphasis on the Central North region, which presented the highest proportion of infected insects. Table 3 shows the positivity rates for trypanosomatids by region, species, stage and site of capture of the triatomines (inside houses or in the peridomestic environment). The highest positivity rate of *T. brasiliensis* and *Panstrongylus* spp. was found in the Southeast region, *T. pseudomaculata* and *Rhodnius* spp. in the Central North region and *T. sordida*

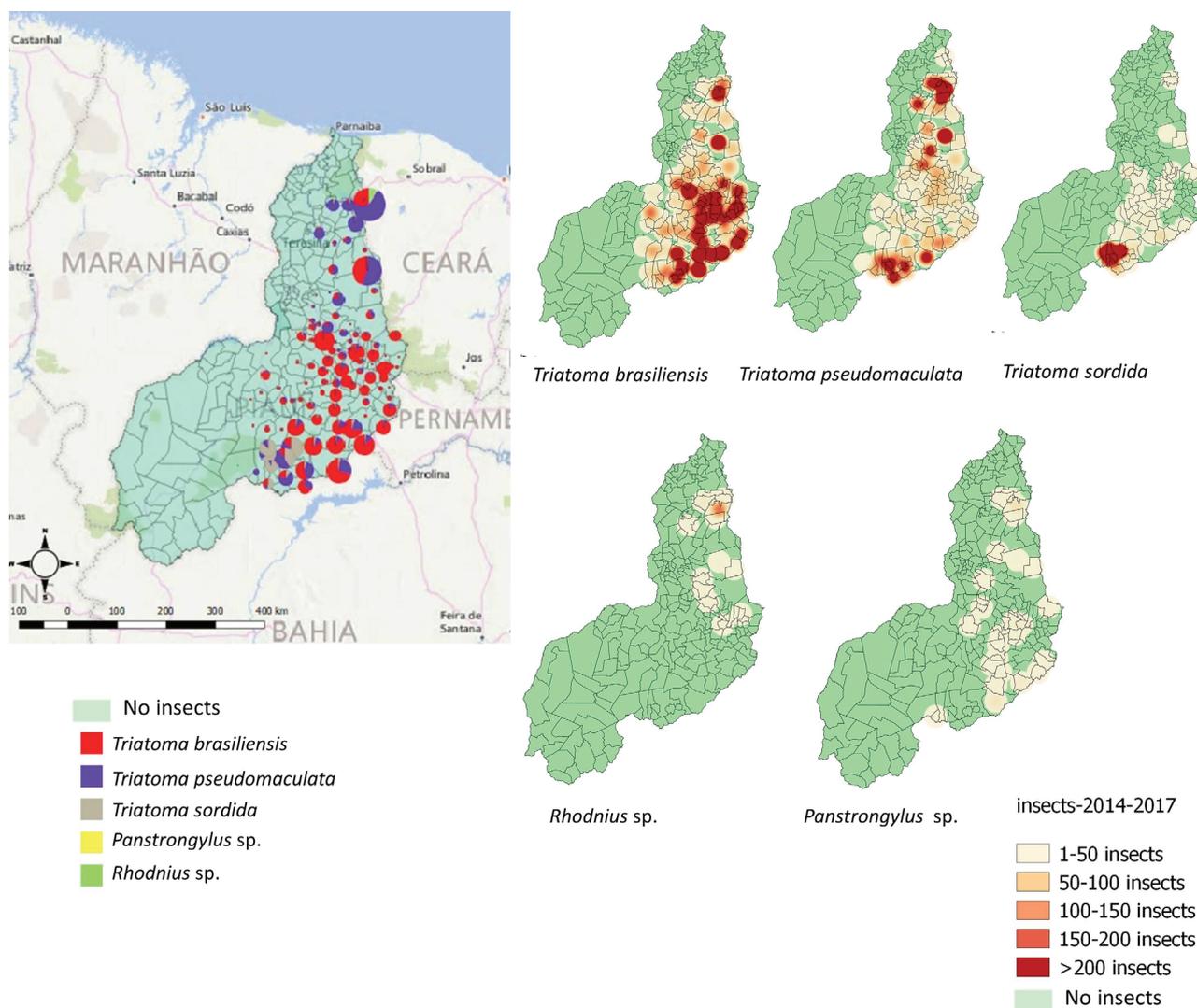


Figure 4 - Geographical distribution of triatomine species in Piauí State from 2014 to 2017.

in the Southwest region. In relation to the capture sites, it was found that both, *T. brasiliensis* and *T. pseudomaculata* presented higher infection rates in nymphs captured inside houses and adults captured in the peridomicile, *T. sordida* in adults captured inside houses and nymphs in the peridomicile, *Rhodnius* spp. and *Panstrongylus* spp. in adults captured in the peridomicile.

DISCUSSION

The greatest challenge of Chagas disease control in Northeastern Brazil has been the fight against triatomines of which there are naturally occurring stocks, and the persistent vulnerability of houses to recolonization by these insects. The present study demonstrates that entomological surveillance activities, which are the basis of vector control, are performed only in some parts of the municipalities of Piauí State. Therefore, many municipalities did not

generate entomological data on vectors of Chagas disease during the studied period, possibly due to the fact that not all triatomines were examined, and/or due to limitations in the microscopic observation of fresh feces and/or the inexperience of technicians³³. Surveillance activities, carried out in the four regions of the State, showed the presence of triatomine species characteristic of the Northeastern region of Brazil, such as *T. brasiliensis* and *T. pseudomaculata*. Unfortunately, the identification data of *Rhodnius* spp. and *Panstrongylus* spp. were restricted to the genus by limitations in taxonomic identification. *Triatoma sordida* was also identified in some municipalities. Comparing the present study with the one carried out in 2010, it is evident that *Triatoma brasiliensis* and *Triatoma pseudomaculata* continue to be the most widely distributed species in Piauí State³⁴.

Triatoma brasiliensis was the most frequently identified species, present in a large proportion of the municipalities

Table 2 - Average number of triatomines at different stages of development and catch sites recorded in the regions of the Piauí State from 2014 to 2017.

	Central-North		North		Southeast		Southwest	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
<i>Triatoma brasiliensis</i>								
Adults inside houses	22.93	45.870	0.76	1.809	41.79	62.597	18.20	51.973
Nymphs inside houses	7.80	12.830	0.44	1.417	16.92	25.394	5.24	13.706
Adults peridomestic	14.80	30.282	1.20	3.819	17.74	27.928	9.50	28.692
Nymphs peridomestic	40.49	88.933	1.92	4.983	43.85	72.975	18.57	49.927
<i>Triatoma pseudomaculata</i>								
Adults inside houses	42.94	90.218	10.08	32.328	4.14	10.387	10.86	26.642
Nymphs inside houses	2.19	4.580	0.32	1.215	0.66	2.080	0.49	2.147
Adults peridomestic	4.31	9.334	1.40	2.677	1.18	3.534	1.77	6.045
Nymphs peridomestic	64.33	144.756	18.44	64.611	2.94	6.901	6.98	18.010
<i>Triatoma sordida</i>								
Adults inside houses	0.04	0.187	0.00	0.000	0.49	2.580	13.85	51.104
Nymphs inside houses	0.00	0.000	0.00	0.000	0.04	0.308	0.53	2.008
Adults peridomestic	.24	1.147	0.00	0.000	0.05	0.338	0.81	2.630
Nymphs peridomestic	0.07	0.460	0.00	0.000	0.12	0.591	8.24	27.267
<i>Rhodnius</i> sp.								
Adults inside houses	1.82	8.570	0.36	1.319	0.01	0.100	0.00	0.000
Nymphs inside houses	0.04	0.187	0.00	0.000	0.00	0.000	0.00	0.000
Adults peridomestic	0.40	1.318	0.60	2.217	0.01	0.100	0.00	0.000
Nymphs peridomestic	1.23	6.314	0.12	0.600	0.00	0.000	0.00	0.000
<i>Panstrongylus</i> sp.								
Adults inside houses	0.38	1.361	0.12	0.600	0.16	0.639	0.15	1.251
Nymphs inside houses	0.07	0.555	0.00	0.000	0.02	0.224	0.00	0.000
Adults peridomestic	1.06	3.316	0.28	0.980	0.45	2.330	0.27	2.053
Nymphs peridomestic	0.14	0.880	0.16	0.800	0.05	0.366	0.00	0.000

of the Southeast, Southwest and Central North regions. In this study, the municipalities that registered the presence of *T. brasiliensis* are located mainly in the semi-arid Caatinga biome. *T. brasiliensis* is a typical species of this region³⁵ and naturally inhabits the cracks of rocky outcrops in the semiarid landscape. The present study shows that *T. brasiliensis* colonizes the interior of houses and documents the presence of nymphs of this species inside households in several municipalities. It is very likely that municipalities in the semiarid region of Piauí State, which did not register surveillance activities, had a similar and hidden entomological framework.

Triatoma pseudomaculata was also collected in several semiarid municipalities, mainly in the Southeast, Southwest and Central North regions. This species is also an important vector of Chagas disease in the Northeastern region of Brazil, in the Caatinga biome, naturally inhabiting the bark

of typical bushes in semiarid areas³⁶. Surveillance data from Piauí State compiled here show *T. pseudoaculata* is colonizing households and the peridomestic environment in many municipalities.

Several species of the genus *Rhodnius* are important vectors of Chagas disease³⁷. In a study carried out in 2010 in the State, *R. neglectus* occurred more frequently in the South (in areas of the cerrado biome), while *R. nasutus* occurred more frequently in the North of the State, in areas of Caatinga, babassu forests in Maranhão and restingas in the Northeast. *R. pictipes* and *R. robustus* occurred only in the extreme North of the State, with a colonization index equal to zero³⁴. The species *R. nasutus* has a natural habitat in the palm tree *Copernicia prunifera* (carnauba), which is the main palm of semiarid areas³⁸. In this study, it was demonstrated that triatomines of the genus *Rhodnius* were captured more frequently in the Central North region which

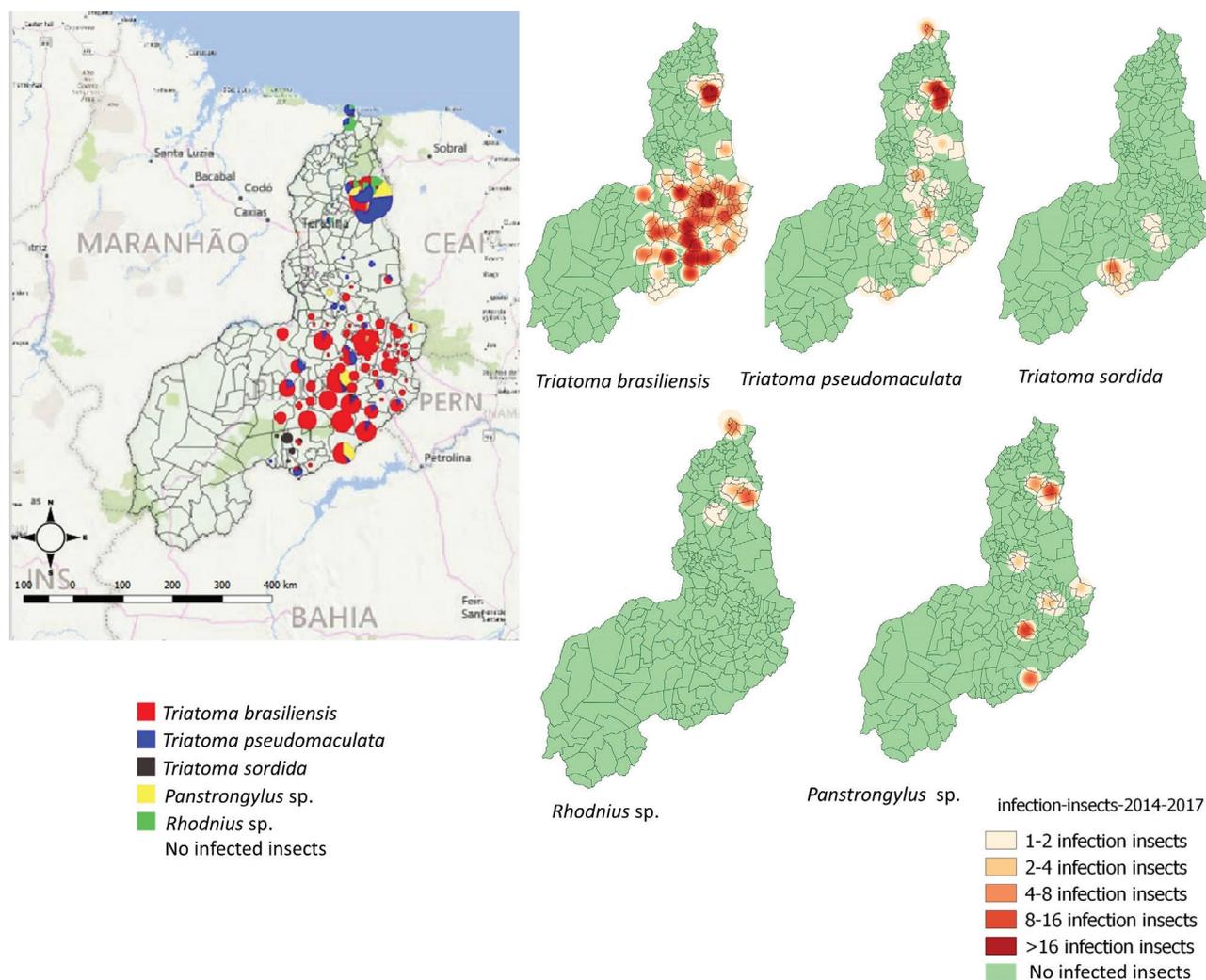


Figure 5 - Geographic distribution of positive insects for trypanosomatids, distinguishing the different vector species of Chagas' disease in Piauí State from 2014 to 2017.

contains the highest occurrence of carnauba and the natural resources of this palm tree are most frequently used by the population.

T. sordida had a particular distribution, being identified in the South of the State. This species has the Cerrado biome as its dispersion epicenter, but it can also be collected in the Cerrado-Caatinga ecotone and even in semiarid areas³⁸. The highest average number of specimens per municipality was observed in the Southwest region of the State, where the Cerrado vegetation predominates, near the border with Tocantins State.

An important finding was the frequent presence of triatomines (including nymphal instar) inside residences in several municipalities, possibly constituting intradomestic colonies of insects feeding on the inhabitants. This finding points to a risk of persistent vector transmission in vast areas of Piauí State, with a preponderance of municipalities in the semiarid territories of the Southeast, Southwest and

Central North regions and of the species *T. brasiliensis* and *T. pseudomaculata*.

As reported above, the physiogeographic characteristics of these regions are extremely favorable to the presence of triatomine species typical of the semiarid territory and the Caatinga biome. In this way the process of colonization of the Northeastern outback, through cattle ranching and subsistence agriculture, was conducted on a territory where the triatomines naturally abound. The peculiar interaction between man and the environment in the semiarid region favors the contact of humans with insects that transmit Chagas disease. This interaction, over three centuries resulted in a stable transmission of *T. cruzi* and the occurrence of Chagas disease at endemic levels in the Brazilian Northeast outback.

Triatomines were successfully controlled by the use of insecticides between the 1970s and 2000s, with a significant reduction in transmission and prevalence

Table 3 - Triatomine positivity rate for *T. cruzi* by region, species, stage and capture site in Piauí State from 2014 to 2017.

	Central-North		North		Southeast		Southwest	
	N	Positive (%)	N	Positive (%)	N	Positive (%)	N	Positive (%)
<i>Triatoma brasiliensis</i>								
Adults inside houses	1,970	9 (0.5%)	19	0 (0.0%)	9,297	115 (1.2%)	2,633	17 (0.6%)
Nymphs inside houses	664	4 (0.6%)	24	0 (0.0%)	3,645	26 (0.7%)	775	5 (0.6%)
Adults in peridomestic areas	1,267	32 (2.5%)	57	1 (1.8%)	3,817	68 (1.8%)	1,410	16 (1.1%)
Nymphs in peridomestic areas	3,489	12 (0.3%)	48	0 (0.0%)	9,890	50 (0.5%)	2,606	7 (0.3%)
<i>Triatoma pseudomaculata</i>								
Adults inside houses	3,758	35 (0.9%)	252	3 (1.2%)	1,037	6 (0.6%)	1,817	5 (0.3%)
Nymphs inside houses	192	1 (0.5%)	9	0 (0.0%)	140	0 (0.0%)	70	0 (0.0%)
Adults in peridomestic areas	377	3 (0.8%)	55	6 (10.9%)	260	6 (2.3%)	253	3 (1.2%)
Nymphs in peridomestic areas	5,533	21 (0.4%)	461	0 (0.0%)	729	2 (0.3%)	1,212	2 (0.2%)
<i>Triatoma sordida</i>								
Adults inside houses	3	0 (0.0%)	0	0 (0.0%)	112	1 (0.9%)	2,113	8 (0.4%)
Nymphs inside houses	0	0 (0.0%)	0	0 (0.0%)	7	0 (0.0%)	70	0 (0.0%)
Adults in peridomestic areas	20	0 (0.0%)	0	0 (0.0%)	10	1 (10%)	110	0 (0.0%)
Nymphs in peridomestic areas	6	0 (0.0%)	0	0 (0.0%)	29	0 (0.0%)	1,214	4 (0.3%)
<i>Rhodnius</i> sp.								
Adults inside houses	153	8 (5.3%)	9	1 (11.1%)	2	0 (0.0%)	0	0 (0.0%)
Nymphs inside houses	3	0 (0.0%)	0	0 (0.0%)	0	0 (0.0%)	0	0 (0.0%)
Adults in peridomestic areas	34	2 (5.9%)	26	7 (26.9%)	3	0 (0.0%)	0	0 (0.0%)
Nymphs in peridomestic areas	103	0 (0.0%)	3	0 (0.0%)	0	0 (0.0%)	0	0 (0.0%)
<i>Panstrongylus</i> sp.								
Adults inside houses	32	1 (3.1%)	3	0 (0.0%)	36	0 (0.0%)	19	4 (21%)
Nymphs inside houses	6	0 (0.0%)	0	0 (0.0%)	4	0 (0.0%)	0	0 (0.0%)
Adults in peridomestic areas	89	12 (13.4%)	7	4 (57.1%)	93	15 (16.1%)	36	3 (8.3%)
Nymphs in peridomestic areas	12	0 (0.0%)	4	0 (0.0%)	9	0 (0.0%)	0	0 (0.0%)

of Chagas disease³⁹. This control policy resulted in the virtual elimination of vector transmission in many areas in Brazil⁴⁰. However, in vast regions of the Northeast, as in many municipalities of Piauí, the actions were discontinued, and the efforts directed to the control of mosquitoes which transmit arboviruses. The strong pressure that the natural environment exerts on human communities in relation to triatomines does not allow the interruption of entomological surveillance activities of Chagas disease and represents a risk of vector transmission of the disease reappearing, particularly in the Brazilian semi-arid region.

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