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Major Article

Insect vectors of Chagas disease (*Trypanosoma cruzi*) in Northeastern Brazil

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Abstract

Introduction: Chagas disease remains a public health problem in the rural and urban areas of 19 countries in the Americas. **Methods:** The aim of the present study was to investigate the *Trypanosoma cruzi* infection rate of triatomines collected from both intra- and peridomiciliary areas in eleven municipalities of Southeastern Ceará, Brazil, from 2009 to 2015. **Results:** A total of 32,364 triatomine specimens, including nymphs and adults, were collected, and 31,736 (98.06%) of these were examined. More nymphs were collected than adults, and the greatest number of triatomines (n = 8,548) was collected in 2010, for which the infection rate was 1.3%, with the highest rate of infections observed for specimens from Quixere. The species collected during the study were identified as *Triatoma pseudomaculata, Triatoma brasiliensis, Panstrongylus megistus, Panstrongylus lutzi,* and *Rhodnius nasutus*, with *T. pseudomaculata* being the most abundant (n = 19,962). **Conclusions:** These results verify the presence of triatomines in both intra- and peridomiciliary areas, thereby ensuring persistence of the pathogen and consequently, the disease, as the presence of infected vectors in households is an important risk factor. According to these findings, the Chagas Disease Control Program should intensify its efforts in order to prevent the spread of the disease.

Keywords: Chagas disease. Triatomine. Infection rate.

INTRODUCTION

Since its discovery by Carlos Chagas in 1909, Chagas disease, which is caused by the flagellated protozoan *Trypanosoma cruzi* and transmitted by hematophagous insect or triatomines, has been a public health problem in rural and urban areas of the 19 American countries colonized by Iberian empires, owing to the migration of its vectors[1]. It is estimated that 8 to 14 million people are infected worldwide[2], especially in Latin America, and more than 100 million are at risk of contracting the disease. Previously, the disease was only found in the American continent. However, due to the intense migratory flows of Latin American populations, Chagas disease is now considered a global problem[3].

Chagas disease is typically transmitted by vectors (80% of cases) when triatomines, while feeding on a host's blood, deposit feces that contain the metacyclic trypomastigote form of *T. cruzi,* which then penetrates the host's skin or mucous membranes. The second transmission route of epidemiological importance is through blood transfusion (5-20% of cases), which, along with international migration, has introduced Chagas disease to non-endemic countries, including Canada, the United States, European countries, and some Eastern Pacific countries[4]. With advances in vector control and transfusion monitoring, alternative routes, such as oral and transplacental transmission, laboratory accidents, animal handling, and organ transplants, have increased in relevance[5]. In recent years, the oral route transmission has increased in northern Brazil, owing to the ingestion of *T. cruzi*-infected foods, such as açai berry and sugarcane[6]. For example, 41 cases of Chagas disease were confirmed in the City of Belém, State of Pará, in 2011 (January to October, with 24 cases in October alone)[7].

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In Brazil, vector transmission occurs in all states of the northeast region and primarily depends on the presence of vectors in households[8]. The northeastern region of Brazil is considered endemic for Chagas disease and is second among the top regions infested by triatomines[9,10], with the State of Bahia harboring the greatest diversity of triatomine species in the country[11,12].

The rural area of the State of Ceará has *caatinga*-type vegetation, and precarious human dwellings, which facilitate the presence of several triatomine species that are important in the transmission of Chagas disease in Ceará: *Triatoma brasiliensis, Triatoma pseudomaculata*, *Panstrongylus megistus*, *Panstrongylus lutzi,* and *Rhodnius nasutus*[13]. These species are the most important in the Brazilian *caatinga* region, with a high invasive potential, and occupy a place in the domestic, peridomiciliary, and wild chain of Chagas disease[11,14].

Since the first studies carried out by Alencar, Chagas disease has been highly prevalent in the State of Ceará (14.8%), especially in the municipality of Limoeiro do Norte[15]. Because of the high number of triatomines captured in Limoeiro do Norte by Vasconcelos in 2013 and the difficulty of controlling *T. brasiliensis* and *T. pseudomaculata* in this municipality[16], we decided to assess the prevalence of Chagas disease (i.e., rates of infestation and triatomine infection) in Southeastern Ceará, where Limoeiro do Norte is located, as well as to identify host species (domiciliary, peridomiciliary, or wild) that contribute to the maintenance and dispersion of *T. cruzi* so that preventive action can be taken to control the disease.

METHODS

Study design and sampling

This is a retrospective descriptive study that was performed using records from the Vector Control Center of Ceará [*Núcleo de Controle de Vetores do Ceará* (NUVET)], of the State Health Secretariat of Ceará State [*Secretaria da Saúde do Estado do Ceará (SESA)*. The data were collected from 2009 to 2015 and included all the municipalities (11 towns) belonging to the 13th Regional Health Coordination (CRES) in Southeastern Ceará: Alto Santo, Ererê, Iracema, Jaguaribara, Jaguaribe, Limoeiro do Norte, Pereiro, Potiretama, Quixeré, São João do Jaguaribe, and Tabuleiro do Norte (**Figure 1A** and **Figure 1B**).

During the study period, both nymph and adult triatomines were collected from intra- and peridomiciliary (chicken coops, barns, pigpens, cattle sheds) areas, and dead triatomines were excluded, as it is not possible to detect *T. cruzi* in dead vectors using the abdominal compression method. In this method, the material obtained from triatomine compression is placed on a microscope slide, along with a drop of 0.9% saline, covered with a coverslip, and then analyzed under an optical microscope.

Data analysis

In order to identify statistical associations between collection site and triatomine species, the data were analyzed using chi-square tests ($p < 0.05$) in GraphPadPrism 5.0. which allowed us to identify statistical associations between collection site and triatomine species. Proportions, infection rates, and infestation rates were estimated using simple percentage calculations.

RESULTS

Triatomine collection

During the seven-year study period, 32,364 triatomine specimens were collected from 11 municipalities in Southeastern Ceará, with 3,155 (9.8%) collected from intradomiciliary areas and 29,209 (90.3%) from peridomiciliary areas, and 31,736 (98.1%) of the specimens were analyzed (**Table 1** and **Table 2**). Of the seven years, the greatest number triatomines (n = 8,548; 25.6%) was collected in 2010, and of the 11 municipalities, the greatest number of triatomines was collected from Tabuleiro do Norte (n = 8,144), followed by Ererê (n = 5,976) and Jaguaribe (n = 4,607; **Table 1**).

Of the 3,155 intradomiciliary specimens, 350 (11.1%), 637 (20.2%), 381 (12.1%), 661 (21.0%), 501 (15.9%), 249 (7.9%), and 376 (11.9%) were collected in 2009, 2010, 2011, 2012, 2013, 2014, and 2015, respectively, and the most frequently collected intradomiciliary species was *T. brasiliensis* (n = 2,368; 75.1%), followed by *T. pseudomaculata* (n = 545; 17.3%; **Table 3** and **Table 4**).

In the present study, more nymphs were collected than adults, from both intra- and peridomiciliary areas, with 1,806 (8.2%) and 20,346 (91.9%) of the nymphs collected from intra- and peridomiciliary areas. More specimens were also collected from peridomiciliary areas (n = 29,209; 90.3%) than intradomiciliary areas.

The triatomines collected from peridomiciliary area included *T. pseudomaculata* (n = 19,417; 66.5%), followed by *T. brasiliensis* (n = 9,469; 32.4%), *R. nasutus* (n = 268; 0.9%), *P. megistus* (n = 30; 0.1%), and *P. lutzi* [n = 25; 0.1% (**Table 3** and **Table 4**)].

There was a statistical association between the occurrence of *T. pseudomaculata* and peridomiciliary areas, whereby the proportions of *T. pseudomaculata* were higher than those of the other species in peridomiciliary areas, and a similar association was noted for *T. brasiliensis* in intradomiciliary areas ($p < 0.001$; **Table 3** and **Table 4**).

Infection rate

A total of 432 triatomines tested positive for *T. cruzi* infection, indicating an infection rate of 1.4% (**Table 2**). The greatest number of infected triatomines (n = 144; 2.7%) was observed in 2009, with more adults being infected than nymphs, and during the same year (i.e., 2009), the greatest infection rate was observed in specimens from Limoeiro do Norte (7.6%), followed by the specimens from Quixeré (3.5%) and Tabuleiro do Norte (3.2%). Specimens from Limoeiro do Norte also yielded the greatest number of infected specimens throughout the entire study period (n = 205), indicating an infection rate of 5.3% (**Table 2**).

DISCUSSION

Triatomine collection

From 1975 to 1980, a national investigation was carried out, during which 15,342 triatomine specimens were collected from northeastern Brazil, and in 1996, the Chagas Disease

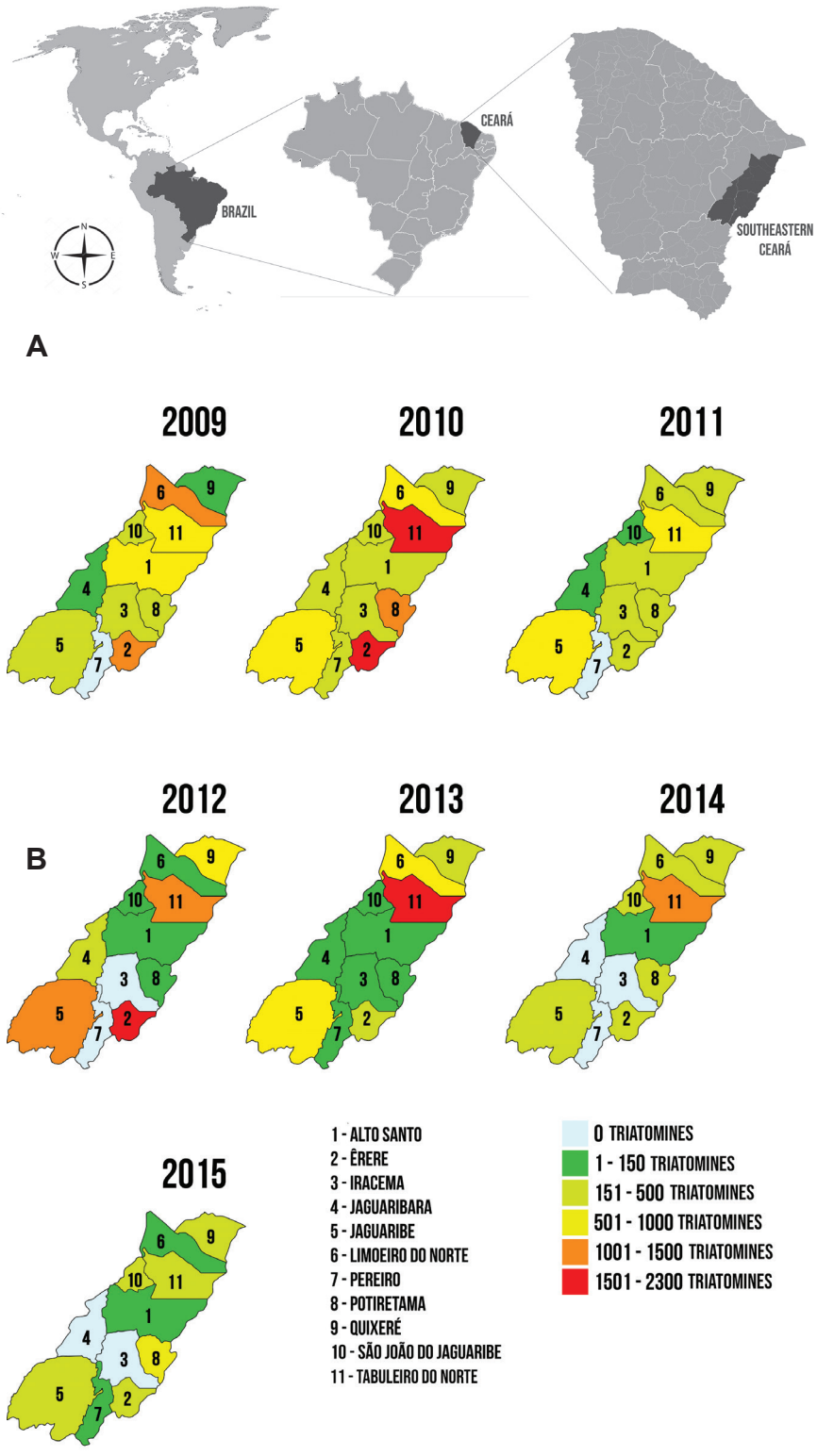

FIGURE 1: A) Map of the American continent highlighting Brazil, Ceará and Southeastern Ceará. **Source:** http://althistory.wikia.com/wiki/File:Americas_map.png; https://openclipart.org/detail/226709/mapa-brasil; https://pt.wikipedia.org/wiki/Lista_de_municípios_do_Ceará (with adaptations). **B)** Data collected in 11 towns Municipalities of the 13th Regional Health Coordination, in Southeastern Ceará, Brazil, from 2009 to 2015. **Source:** http://pt.wikipedia.org (with adaptations).

TABLE 1: Frequency of triatomines collected in Southeastern Ceará, Brazil, from 2009 to 2015.

Municipality	Years							
	2009	2010	2011	2012	2013	2014	2015	Total
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Alto Santo	533 (9.6)	483 (5.6)	169 (3.9)	83 (1.5)	13 (0.3)	51 (2.0)	28 (1.5)	1,360 (4.2)
Ererê	1,426 (25.8)	1,533 (17.9)	330 (7.6)	1,914 (34.5)	198 (5.0)	245 (9.5)	330 (17.5)	5,976 (18.5)
Iracema	391 (7.1)	329 (3.9)	311 (7.2)	NA	1 (0.02)	NA	NA	1,032 (3.2)
Jaguaribara	113 (2.1)	285 (3.33)	119 (2.8)	262 (4.7)	13 (0.3)	NA	NA	792 (2.4)
Jaguaribe	437 (7.9)	841 (9.8)	972 (22.5)	1,236 (22.2)	751 (19.0)	204 (7.9)	166 (8.8)	4,607 (14.2)
Limoeiro do Norte	1,206 (21.8)	921 (10.8)	396 (9.1)	39 (0.7)	1,020 (25.9)	281 (10.9)	15 (0.8)	3,878 (12.0)
Pereiro	NA	194 (2.8)	NA	NA	94 (2.9)	1 (0.03)	5 (0.3)	294 (0.9)
Potiretama	375 (6.8)	1,016 (11.9)	420 (9.7)	32 (0.6)	4 (0.1)	420 (16.2)	599 (31.8)	2,866 (8.9)
Quixeré	87 (1.6)	416 (4.9)	492 (11.4)	657 (11.8)	163 (4.0)	199 (7.7)	328 (17.4)	2,342 (7.2)
São João do Jaguaribe	209 (3.8)	308 (3.6)	120 (2.8)	91 (1.6)	166 (4.2)	163 (6.3)	46 (2.5)	1,103 (3.4)
Tabuleiro do Norte	757 (13.7)	2,222 (26.0)	997 (23.0)	1,242 (22.4)	1,509 (38.3)	1,022 (39.5)	365 (19.4)	8,114 (25.1)
Total	**5,534 (100.0)**	**8,548 (100.0)**	**4,326 (100.0)**	**5,556 (100.0)**	**3,932 (100.0)**	**2,586 (100.0)**	**1,882 (100.0)**	**32,364 (100.0)**

NA: data was not collected. **Source:** Vector Control Center of Ceará.

TABLE 2: Frequency of examined and infected triatomines collected in southeastern Ceará, Brazil, from 2009 to 2015.

Municipality	Years															
	2009		2010		2011		2012		2013		2014		2015		Total	
	No. exam.	No. infect.	No. exam.	No. infect.	No. exam.	No. infect.	No. exam.	No. infect.	No. exam.	No. infect.	No. exam.	No. infect.	No. exam.	No. infect.	No. exam.	No. infect.
		(%)		(%)		(%)		(%)		(%)		(%)		(%)		(%)
Alto Santo	532	7	481	0	169	1	83	2	13	0	51	0	28	0	1,357	10
		(1.3)				(0.59)		(2.41)								(0.73)
Ererê	1281	9	1,491	1	330	0	1,894	4	198	0	245	0	330	0	5,769	14
		(0.7)		(0.1)				(0.2)								(0.2)
Iracema	389	1	329	1	311	0	NA	NA	1	0	NA	NA	NA	NA	1,030	2
		(0.3)		(0.3)												(0.2)
Jaguaribara	113	00	284	0	119	0	262	0	13	0	NA	NA	NA	NA	791	0
Jaguaribe	435	2	754	5	972	0	1,232	1	751	1	204	0	166	0	4,514	9
		(0.5)		(0.7)				(0.1)		(0.1)						(0.2)
Limoeiro do Norte	1,198	91	905	33	396	1	39	26	1,020	32	280	15	15	7	3,853	205
		(7.6)		(3.7)		(0.25)		(66.7)		(3.1)		(5.4)		(46.7)		(5.3)
Pereiro	NA	NA	194	0	NA	NA	NA	NA	94	0	01	1	05	0	294	1
												(100.0)				(0.3)
Potiretama	368	4	1,009	09	419	0	32	0	4	0	420	0	599	0	2,851	13
		(1.1)		(0.9)												(0.5)
Quixeré	86	3	299	17	492	1	556	13	163	16	199	2	328	4	2,123	56
		(3.5)		(5.7)		(0.20)		(2.3)		(9.3)		(1.0)		(1.2)		(2.6)
São João do Jaguaribe	207	3	308	2	120	0	91	6	166	5	163	0	46	1	1,101	17
		(1.5)		(0.7)				(6.6)		(3.0)				(2.2)		(1.5)
Tabuleiro do Norte	757	24	2,166	39	996	0	1,238	25	1,509	9	1,022	4	365	4	8,053	105
		(3.2)		(1.8)				(2.0)		(0.6)		(0.4)		(1.1)		(1.3)
Total	**5,366**	**144**	**8,220**	**107**	**4,324**	**3**	**5,427**	**77**	**3,932**	**63**	**2,585**	**22**	**1,882**	**16**	**31,736**	**432**
		(2.7)		**(1.3)**		**(0.1)**		**(1.4)**		**(1.6)**		**(0.9)**		**(0.9)**		**(1.4)**

No. exam: number of vectors examined. **No. infect. (%)**: Number of positive results (infection rate). **NA:** data was not collected. **Source:** Vector Control Center of Ceará.

TABLE 3: Frequency of triatomines collected in southeastern Ceará, Brazil, from 2009 to 2011.

Species	Years											
	2009				2010				2011			
	Intra		Peri		Intra		Peri		Intra		Peri	
	A	N	A	N	A	N	A	N	A	N	A	N
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Triatoma brasiliensis	66	126	150	864	255	269	561	1,645	99	185	396	947
	(45.2)	(61.8)	(11.2)	(22.5)	(83.1)	(81.5)	(26.4)	(28.4)	(74.4)	(74.6)	(3.0)	(36.1)
Triatoma pseudomaculata	55	74	1,166	2,939	34	60	1,526	4,120	28	60	909	1672
	(37.7)	(36.3)	(86.88)	(76.5)	(11.1)	(18.2)	(71.8)	(71.2)	(21.1)	(24.2)	(68.9)	(63.7)
Panstrongylus megistus	1	0	3	8	2	0	3	0	1	0	8	1
	(0.7)		(0.22)	(0.2)	(0.7)		(0.1)		(0.8)		(0.6)	(0.1)
Panstrongylus lutzi	7	0	2	02	10	01	2	6	2	3	2	5
	(4.8)		(0.15)	(0.1)	(3.3)	(0.3)	(0.1)	(0.1)	(1.5)	(1.2)	(0.2)	(0.2)
Rhodnius nasutus	17	4	21	29	6	0	34	14	3	0	4	1
	(11.6)	(2,0)	(1.56)	(0.8)	(2.0)		(1.6)	(0.2)	(2.3)		(0.3)	(0.1)
Total	**146**	**204**	**1,342**	**3,842**	**307**	**330**	**2,126**	**5,785**	**133**	**248**	**1,319**	**2,626**

Intra: Intradomiciliary. Peri: Peridomiciliary. **A (%):** Number of adults (% total number of individuals). **N (%):** Number of nymphs (% total number of individuals). **Source:** Vector Control Center of Ceará.

Control Program collected 290,576 specimens, of which 201,156 (69.2%) were collected from northeast Brazil. Of the total number of triatomines collected in the northeast, 64,714 (32.2%) were collected from Ceará alone[11]. Even after more than 30 years of research and efforts aimed at controlling Chagas disease, the results of the present study are still very similar and the number of triatomines collected remains very high. Another study, which was conducted in Jaguaruna, Ceará, over a three-year period (2000 to 2002), collected 3,082 triatomines[17], which is ten-fold fewer than the number collected NUVET from 2009 to 2015. Therefore, despite advances in vector control, Southeastern Ceará still harbors a large population of triatomines.

In addition, more nymphs (n = 22,152, 68.5%) were collected than adults (n = 10,212, 31.6%) during the present study, thereby corroborating the results of Vasconcelos et al. who collected three times more nymphs (n = 2,204) than adults (n = 659) from Limoeiro do Norte in 2013[16].

These findings indicate, according to WHO entomological indicators, that triatomine colonization is still occurring and reinforce statements by Coura, in 2008, and Coura and Viñas, in 2010, that man, through burning and other changes to natural triatomine habitat, has forced these insects to adapt to manmade environments. Coura and Borges-Pereira, in 2012, stated that the adaptation of triatomines to household environments might be the most concerning matter of Chagas disease transmission[4,18,19].

In the present study, *T. pseudomaculata* was the most frequently collected species in all the municipalities, except Quixeré, in which *T. brasiliensis* predominated. These results differ from those reported by Sarquis et al.[17], who collected 3,082 triatomines in Jaguaruana, Ceará, from 2000 to 2002, with 2,307 (74.9%) identified as *T. brasiliensis* and 229 (7.4%) identified as *T. pseudomaculata* specimens, but corroborate the results of Vasconcelos et al., who also collected a higher proportion of *T. pseudomaculata* specimens, Limoeiro do Norte from 2006 to 2009[16]. A notable aspect of *T. pseudomaculata* is that is a low-efficacy vector, in that only 10% of *T. cruzi* within the species are able to develop into the infectious metacyclic form[19]. Therefore, the risk that these specimens contribute to the transmission of Chagas disease is relatively low.

Nevertheless, *T. pseudomaculata* have been reported to colonize dwellings in Berilo, Minas

TABLE 4: Frequency of triatomines collected in southeastern Ceará, Brazil, from 2012 to 2015.

Species	Years															
	2012				2013				2014				2015			
	Intra		Peri		Intra		Peri		Intra		Peri		Intra		Peri	
	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Triatoma brasiliensis	162	347	618	1,177	151	232	444	1,257	62	111	321	671	105	198	116	302
	(63.3)	(85.7)	(35.7)	(37.2)	(63.5)	(88.2)	(41.7)	(53.1)	(53.0)	(84.1)	(43.9)	(41.8)	(69.1)	(88.4)	(21.2)	(31.5)
Triatoma pseudomaculata	46	41	1,068	1,949	39	19	613	1,103	24	11	369	913	28	26	424	646
	(17.9)	(10.1)	(61.6)	(61.6)	(16.4)	(7.2)	(57.6)	(46.6)	(20.5)	(8.3)	(43.9)	(56.9)	(18.4)	(11.6)	(77.4)	(67.4)
Panstrongylus megistus	0	0	1	6	3	11	0	0	1	0	0	0	1	0	0	0
			(0.1)	(0.2)	(1.3)	(4.2)			(0.9)				(0.7)			
Panstrongylus lutzi	10	1	03	1	16	0	0	1	06	10	1	0	7	0	0	0
	(3.9)	(04)	(0.2)	(0.03)	(6.7)			(0.04)	(5.1)	(7.6)	(0.14)		(4.6)			
Rhodnius nasutus	38	16	43	29	29	1	7	6	24	0	40	22	11	0	8	10
	(14.8)	(6.3)	(2.5)	(0.93)	(12.2)	(0.4)	(0.8)	(0.3)	(20.5)		(5.5)	(1.4)	(7.2)		(1.5)	(1.0)
Total	**256**	**405**	**1733**	**3162**	**238**	**263**	**1064**	**2367**	**117**	**132**	**731**	**1606**	**152**	**224**	**548**	**958**

Intra: Intradomiciliary. **Peri:** Peridomiciliary. **A (%):** Number of adults (% total number of individuals). **N (%):** Number of nymphs (% total number of individuals). **Source:** Vector Control Center of Ceará.

Gerais[20], and in the urban area of Sobral, Ceará[21]. Because the species is well-adapted to high temperatures, it is usually found in roofs and other parts of buildings that receive generous amount of sun[22], thereby making such sites more significant in terms of *T. cruzi* transmission[23]. Chagas disease has been endemic to Ceará since the 1940s, as reported by Alencar et al.[24]. Lima et al.[25] collected 829 R. nasutus specimens from palm trees in the rural and peri-urban areas of Jaguaruana, Ceará, and Dias et al.[26] reported that palm trees are the natural habitat of *Rhodnius* spp. and that microclimate plays an important role in the interaction of *Rhodnius* spp. and palm trees. However, in the present study, 417 *R. nasutus* specimens were collected from homes, rather than from palm trees.

Freitas et al.[27] reported that *R. nasutus* specimens occur in households more frequently during the period when carnauba trees are pruned and suggested that anthropogenic environmental degradation contributes to the domiciliation of triatomines and facilitates vector transmission of Chagas disease in the municipality of Limoeiro do Norte.

A study carried out in the municipality of Russas, Ceará, from 2008 to 2009, reported a high (28.6%) prevalence of *T. cruzi* infection among 761 triatomine specimens, mostly *Triatoma brasiliensis*[22], and Silva et al.[28] reported an infection rate of 8.8% for triatomines collected from 113 municipalities in the State of Pernambuco, most inside households, in 2006 and 2007, with *P. lutzi* exhibiting the highest rates of natural infection. Therefore, we recommend that Chagas disease surveillance and vector control should be improved in the State of Pernambuco.

The gradual reduction in specimens collected by NUVET from 2009 to 2015 may have been influenced by control program success, improvement of housing, and improvement of the sanitary habits of the population. Otherwise**,** it may be the result of worsening triatomine control programs, owing to reduced funding, as investments in control programs for other emerging diseases, such as dengue fever and Zika virus, have increased. Together, these results indicate that efforts to educate populations in recognizing triatomines and notifying health authorities should be extended and reinforced in order to ensure that the disease is controlled in places where it is still found.

Infection rate

Even though the infection rate of *T. brasiliensis* was relatively low (0.8%) in the present study, Sarquis et al.[17] reported an infection rate of 15.3% for the species, and many other studies have reported *T. brasiliensis* as the most frequently collected and infected species[29,30]. Therefore, *T. brasiliensis* likely plays an important role in the transmission of Chagas disease in the northeast region and, especially, in the State of Ceará. Meanwhile, the infection rate of *R. nasutus* (24.3%) in the present study was similar to the rate reported by Vasconcelos et al.[16] (19.4%).

Food eclecticism

In the present study, *P. megistus* was the least frequently collected species, with only 50 specimens collected in total. This is in contrast to the findings of Villela *et al*. who reported that *P. megistus* was the most frequently collected species in the State of Minas Gerais, with a total of 1,380 specimens (99.3% of all triatomines) collected from 2003 to 2007. However, this finding was expected as the species predominates triatomine communities in midwestern, eastern, and southeastern Brazil[31,32]. In addition, some authors have reported that *P. megistus* exhibits food eclecticism, feeding on the blood of birds, humans, cats, and other animals, with human blood being the second most frequently observed in their digestive tracts[33,34].

Moreover, 60-70% of *T. cruzi* in *P. megistus* are able to transform into the form that infects humans and other vertebrates[19]. Therefore, according to Perlowagora-Szumlewicz[34], who reported that metacyclogenesis is one of the most important factors in disease transmission, this species may pose a risk of Chagas disease transmission, even though it was relatively infrequent.

Similarly, *P. lutzi* was also relatively infrequent but is still a concern for Chagas disease transmission as the species food eclecticism[32,35], a factor in the transmission of Chagas disease, and because it is considered one of the most important secondary species for Chagas disease maintenance, owing to its high rates of natural infection and great capacity for household invasion, as it can fly into dwellings. This species also exhibited the highest rates of infection in the present study.

Considering all the observations and limitations of the present study, it can be concluded that the municipalities of Southeastern Ceará need to intensify their surveillance efforts, in order to prevent the colonization of intra- and peridomiciliary areas by these species, and because nymphs were more prominent than adults, suggesting domiciliation and a higher risk of infection for the exposed population, this is especially important for households.

Although the infection rates observed in the present study were relatively low, when compared to previous studies, the infestation rate of each municipality was quite high, which confirms that Chagas disease is still a matter of concern.

Therefore, considering that the presence of infected vectors in the household is an important risk factor for the transmission of Chagas disease, the Chagas Disease Control Program should intensify its efforts in order to prevent the spread of the disease.

The involvement of the populace is also crucial for establishing and maintaining permanent epidemiological surveillance.

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Conflicts of interest

The authors declare that there is no conflict of interest.

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