Do the new triatomine species pose new challenges or strategies for monitoring Chagas disease? An overview from 1979-2021

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Chagas disease persists as one of the most important, and yet most neglected, diseases in the world, and several changes in its epidemiological aspects have been recorded since its discovery. Currently, some of the most relevant changes are related to: (i) the reduction in the incidence of the endemic due to the control of the most important vectors, Triatoma infestans and Rhodnius prolixus, in many countries; (ii) the migration of human populations spreading cases of the disease throughout the world, from endemic to non-endemic areas, transforming Chagas disease into a global threat; and (iii) new acute cases and deaths caused by oral transmission, especially in the north of Brazil. Despite the reduction in the number of cases, new challenges need to be responded to, including monitoring and control activities aiming to prevent house infestation by the secondary vectors from occurring. In 1979, Lent & Wygodzinsky(¹) published the most complete review of the subfamily Triatominae, encompassing 111 recognised species in the taxon. Forty-two years later, 46 new species and one subspecies have been described or revalidated. Here we summarise the new species and contextualise them regarding their ecology, epidemiologic importance, and the obstacles they pose to the control of Chagas disease around the world.

Key words: American Trypanosomiasis - vectors - Triatominae subfamily

Despite the great achievements in controlling Chagas disease, also known as American Trypanosomiasis, major problems are still to be solved in Latin American countries.² No vaccines or drugs are currently available to cure the chronic phase of this disease that affects six million people around the world and has its epidemiology constantly changing because of ecological, climatic, social, political, and technical factors.³,⁴,⁵,⁶

The most effective action in terms of Chagas disease control is the elimination of its vectors from the human dwellings⁷ and, as a means to achieve this goal, four multigovernmental initiatives were launched (South America, Andean countries, Mexico and Central America, Amazon) targeting the three most important triatomine species that transmit the etiological agent Trypanosoma cruzi: Triatoma infestans (Klug, 1834) (southern South America), Rhodnius prolixus Stål, 1859, and T. dimidiata (Latreille, 1811) (northern South America and Central America). The most remarkable achievement resulting from these initiatives was the elimination of the T. infestans domiciliated populations in Brazil, Chile, Uruguay, various provinces in Argentina, and several regions in Paraguay.⁸ More recently, the elimination of the domiciliary infestations of R. prolixus from Central America,⁹ has also been considered a significant accomplishment regarding the battle against vectorial Chagas disease transmission.

Carlos Chagas¹⁰ described the disease in 1909, when the great majority of cases were due to vectorial transmission by the triatomine bug T. infestans, the species most well adapted to human dwellings in many countries in Latin America. Later, several other possibilities of transmission were attested, such as those observed as the result of the donation of infected blood or organs, or the ingestion of contaminated food, mother-child transmission and because of laboratory work accidents.¹¹,¹²,¹³,¹⁴

More than 10 years after the certification of the elimination of the vectorial transmission by T. infestans in some countries, the illness remains as one of the most important neglected diseases and is now spreading into some non-endemic areas because of human migrations.¹⁵,¹⁶ Countries such as Australia, Canada, Japan, Spain, and the United States of America are the most affected by immigrants infected by T. cruzi.¹⁷,¹⁸,¹⁹,²⁰,²¹,²²,²³ Furthermore, climatic and environmental changes may develop new behavioral patterns and adaptations of the triatomines, causing unexpected occurrences of transmission to be recorded.²⁴ Oral transmission, for instance, has been causing new acute cases and deaths, especially in the North of Brazil and Venezuela.²⁵,²⁶,²⁷ An important factor of oral transmission is the proximity of humans to infected vectors. Therefore, vectors also represent a key-factor for this kind of contamination. According to Dias et al.,²⁸ new epidemiological situations have been observed.
in the last years. T. infestans has been eliminated in large geographic areas but remains infesting natural and artificial ecotopes in the Chaco region, especially in Argentina,[38,39] while a similar situation can be observed in northern South and Central America regarding R. prolixus.[40] Additionally, the invasion of houses by T. tibiamaculata (Pinto, 1926) in Salvador (Bahia, Brazil) also stresses the importance of continuously monitoring the vectors.[40] In conclusion, understanding the biology and ecology of the triatomines and their associations with humans is crucial to avoid new cases of Chagas disease.[31,32,33,34]

The objective of this review is to summarise the new species described after 1979, when Lent & Wygodzinsky[41] published the most complete review about the Triatominae subfamily. In this review we contextualise the new vector species regarding their ecological characteristics, epidemiological importance, and the new obstacles they pose to the monitoring and control of Chagas disease around the world.

Triatominae until 1979

Triatomines have been known since the 18th century, when the first species, T. rubrofasciata (De Geer, 1773), first called “Cimex rubrofasciatus” (De Geer, 1773), was described in Indonesia. At that time, this tropicopolitan species was not recognised as a potential vector. Several other Triatominae species had been described before the discovery of the disease, such as T. infestans and Panstrongylus megistus (Burmeister, 1835); the latter being the first species to be shown as a vector in the endemic areas of the State of Minas Gerais, Brazil. However, 136 years passed after the description of T. rubrofasciata until the disease was described by Carlos Chagas. Despite the difficulties in proving the existence of the new disease in a region plagued by a great number of other illnesses, the Brazilian physicist Carlos Chagas described not only its symptoms and the process of adaptation of the triatomines to human dwellings but the disease was described by him. Some of the difficulties found in this region also stresses the importance of continuously monitoring the vectors.[41]

Native vectors

Rhodnius prolixus is the main Chagas disease vector in Venezuela, Colombia, and certain areas of Central America, where it can build up large colonies inside human domiciles.[49] The other two main species implicated in Chagas disease eco-epidemiology in Central American countries are T. dimidiata and R. pallescens Barber, 1932.[49] The members of the T. phyllosoma complex (Meccus Stål, 1859 in some literature) are also found invading and colonising human domiciles in Mexico.[49]

The current scenario is quite challenging in Brazil, where there are 66 triatomine species recorded, of which 37 are native. Therefore, the country presents the highest diversity in this group of insects.[33,34,35,36,37,38,39,40]

It is also important to highlight that more than 20 triatomine species have already been recorded in the Brazilian Amazon Forest,[55,56,57,58,59,60] which corresponds to roughly 40% of the Brazilian territory and is one of the richest areas on the planet in terms of biodiversity.[61] Some of the difficulties found in this region are: (i) the lack of data on the habitats of the newly described triatomines; (ii) triatomines that may be losing their natural habitats because of environmental changes; (iii) the very probable existence of undescribed spe-
cies, and (iv) the lack of detailed studies on the species already recorded in the area. These factors impede an accurate estimate of the risk of dissemination of the Chagas disease in the Amazon.\(^{62}\)

**Triatomiinae after 1979**

Since the publication of the remarkable Lent & Wygodzinsky\(^{63}\) monograph in 1979, describing and illustrating 111 triatomines, 46 species and one subspecies have been described as new or revalidated. They were included in 12 of the 19 genera of the subfamily, which now represent 157 known species (154 living species and three fossils) from 15 countries,\(^{62,63,64,65,66,67,68}\) plus a subspecies\(^{69}\) (Table). Out of those 47 triatomines, 17 are from Brazil, followed by Mexico and Colombia, each with four species (post-1979). In the remainder 12 countries, 22 triatomines have been recorded, and the numbers varied from one to two in each one (Table, Figure).

Twenty-one of the 47 new or revalidated taxa (post-1979) belong to the genus *Triatoma* Laporte, 1832, nine to *Rhodnius* Stål, 1859, and four to *Panstrongylus* Berg, 1879 (Table). The fact that 34 of the 47 newly validated triatomines belong to three genera with the highest medical importance is noteworthy. However, among them, only five show clues of house invasion or domiciliation. The three first triatomines, *T. juazeirensis* Costa & Felix, 2007, *T. b. macromelasoma* Galvão, 1956, and *T. sherlocki* Papa et al., 2002, are included in the *T. brasiliensis* species complex.\(^{69,70,71}\) *Triatoma bahiensis* Sherlock & Serafim, 1967 and *T. melanica* Neiva & Lent, 1941 were also included in that species complex and eventually invade houses, but have not exhibited signals of domiciliation yet.\(^{72,73}\) The fourth triatомine, *T. rosai* Alevi et al. is able to colonise a great diversity of natural ecotopes and is also found infesting domiciliary and peridomestic areas in Argentina, as well as in Bolivia and Paraguay.\(^{68,74}\) The fifth species, *T. huehuetenanguiensis* was found naturally infected by *T. cruzi* in domestic ecotopes.\(^{65}\)

The two exceptions of triatomines (Table) collected in the intradomicile without clues of domiciliation or frequent invasion are the *Belminus* species, *B. corredori* and *B. ferronegen*, known to be sylvatic species. Both were captured in Colombia, inside dwellings.\(^{75,76}\) Since then, no further report on these species in domiciliary ecotopes have been made. Therefore, it is highly probable that those specimens invaded the houses when they were captured.

In this sense, the great majority, 42 of the 47 triatomines listed post-1979, do not appear to be capable of changing the epidemiology or the currently known *T. cruzi* transmission profiles to human populations (Table).

**Valid species and the importance of integrative analysis**

*Rhodnius amazonicus* Almeida, Santos & Sposina, 1973 and *R. zeledoni* Jurberg Rocha & Galvão, 2009 are triatomines of rare occurrence, recorded in the north and northeastern Brazil.\(^{77,78}\) However, they still need to have their taxonomic status confirmed molecularly.\(^{79}\) It is applied also to a Bolivian species - *T. boliviana* Martinez et al., 2007, related to *T. nigromaculata* (Stål, 1859).\(^{80}\) The confirmation of the specific status of species of the genus *Rhodnius* by means of molecular data and experimental crossings proved to be extremely important in the face of the events of cryptic speciation and phenotypic plasticity of the species.\(^{66,67}\) *Rhodnius taquaruussensis* Rosa et al., 2017, for example, was recently synonymised with *R. neglectus* after applying molecular analyses.\(^{66}\) *T. rosai* is closely related to *T. sordida* and was characterised based on integrative taxonomy which is crucial for describing and characterising new taxa. Unfortunately, at times, the integrative taxonomy cannot be carried out as is the case of the recently described species *R. micki* Zhao, Galvão & Cai, 2021. Its characterisation was based on morphological and geometric morphometrics analysis using specimens from a collection.\(^{81}\)

In regard to the Triatomiinae, phenotypic variability has been observed in several taxa, so the multidisciplinary approach is mandatory to avoid misinterpretation of the intra specific variations. Natural hybridisation, which generates phenotypic variation, has been recently explored in the triatomine group and could be more common than already recorded.\(^{62,63,64,65}\) For example, in a natural hybrid zone identified in the State of Pernambuco, Brazil, 13 phenotypes (nine of them intermediate between *T. b. brasiliensis* and *T. juazeirensis*) were revealed for *T. brasiliensis* complex, based on molecular analysis.\(^{82}\) On the other hand, the possibility of the existence of new species due to the detection of genetic variations in taxa that are now considered a single taxon, such as *Mepraia* Mazza, Gajardo & Jörg, 1940;\(^{87}\) *R. pallescens* Barber, 1932;\(^{88}\) *T. patagonica* Del Ponte, 1929;\(^{89}\) *T. costalimai* Verano & Galvão, 1958;\(^{90}\) and *R. ecuadoriensis*\(^{81,92,93,94}\) was demonstrated.

It is crucial to highlight that in the triatomine group the descriptions of new species in the *T. brasiliensis*, *T. sordida*, *T. dimidiata*, and *Mepraia* complexes, as well as in some *Rhodnius* species, were due to integrative analysis using morphological, isoenzymatic, chromosomal and molecular studies that detected population variations compatible with the existence of species and cryptic species. A detailed comprehensive review of these cases was presented by Monteiro et al.\(^{95}\)

**Variety of ecotopes and the challenges of the control programs**

A notorious variety of ecotopes of the triatomines described or revalidated post-1979 was recorded. The ecotopes are in accordance with the previous knowledge of the triatomine group as mentioned in Lent & Wygodzinsky.\(^{10}\) For instance, most of the species of the *Triatoma* genus were recorded occupying rocky outcrops ecotopes, except for *T. rosai* related to distinct natural ecotopes. While *Rhodnius* species have as the primary habitat different species of palm trees, species of *Panstrongylus* genus are predominantly associated with burrows and tree cavities in their primary habitats.\(^{32}\) However, as above-mentioned, these three genera exhibit species with the ability to adapt to the anthropic environment - a process known as domiciliation.\(^{39,96,97}\)

In addition to the domiciliary infestation, it is important to mention the vector control programs are not strongly supported by governmental institutions or are
| Genus | Species | Author | Year | Type locality | Distribution | Collection (Type) | Ecoreg | DNA sequence |
|-------|---------|--------|------|---------------|--------------|-------------------|--------|--------------|
| Belminus | malheroi | Serra, Atzingen & Serra | 1987 | Jauá (1) | Pará, Brazil | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Dwellings | - |
| | coreadori | Galvão & Angulo | 2006 | San Gil (2) | Santander, Colombia | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Dwellings | - |
| | ferraeae | Sandoval, Pabón, Jurberg & Galvão | 2007 | Toledo (3) | North Santander, Colombia | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Dwellings | - |
| | laporrei | Lent, Jurberg & Carcavallo | 1995 | Uringa (4) | Pará, Brazil | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | - | - |
| | pitteri | Osuna & Ayala | 1993 | Rando Grande (5) | Anguia, Venezuela | Colección de Insectos, Francisco Fernandez Yépez del Museo del Instituto de Zoología Agrícola (MIZA) | High altitude | - |
| Cavernicola | lenti | Baret & Arias | 1985 | Balbina (Hidroelectric) (6) | Amazon, Brazil | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Hollow tree | 18S |
| | matsunoi | (Fernández-Loayza) | 1989 | Pan (7) | Patar, Peru | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | - | - |
| Lithosciaus | karapus | Galvão, Patterson, Rocha & Jurberg | 2002 | Kalakkadu (8) | Tamil Nadu State, India | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Rock formation | 28S, 16S, 18S |
| Mecus | bassolae | (Alejandre-Aguilar et al.) | 1999 | San Jerónimo, Xayacatlán (9) | Puebla, Mexico | Collection of Parasitology Department in ENCIB-IPN, Mexico | - | Cytb, 28S |
| Mepridae | gajardoi | Fias, Henry & Gonzalez | 1998 | Arica (10) | Caleta Vizcaya, Chile | Insect Collection of the Institute of Entomology, Universidad Metropolitana de Ciencias de la Educación, Santiago, Chile | Coastal desert | Cytb, COI |
| | parapartica | Fias | 2010 | Pan de Arriague National Park (11) | Atacama, Chile | Collection of the Institute of Entomology, Universidad Metropolitana de Ciencias de la Educación (UEMCE), Santiago, Chile | Coastal area | Cytb, COI |
| Neostrongylus | confusa | Oliveira, Ayala, Juri, Rosa & Galvão | 2012 | Cuba | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | - | - |
| | mexicana | Ponair | 2019 | Hukawng Valley (13) | Kachin, Myanmar | Ponair Amber collection, Oregon State University | Ambar | - |
| | hispaniolae | Ponair | 2013 | La Tosa Amber mine, Cordillera Septentrional (14) | Dominican Republic | Ponair Amber Collection, Oregon State University | Ambar | - |
| Panstrongylus | martinezzorum | Ayala | 2009 | Carapao River (15) | Puerto Ayacucho, Venezuela | Museo de Zoología Agrícola Francisco Fernández Yépez (MIZA), Universidad Central de Venezuela, Maracay | - | - |
| | miliaraensis | Bérenger & Blanchet | 2007 | Border of French Guiana with Brazil (16) | French Guiana | Department of Hemiptera, Museum National d'Histoire Naturelle, Paris, France | - | - |
| | sherlocki | Jurberg, Carcavallo & Lent | 2008 | Santo Inicio (17) | Bahía, Brazil | Rodolfo Carcavallo Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | 200-500m altitude | - |
| Amazonicola | amazonicus | Almeida, Santos & Sposina | 1973 | Bacacuara (18) | Amazon, Brazil; French Guiana (Caco, Sadi) | INPA, Instituto Nacional de Pesquisas da Amazônia, Manaus, Brazil | - | - |
| | barretti | Abad-Franch, Palomo & Monteiro | 2013 | Puerto Ayacucho (19) | Departamento de Putumayo, Colombia; Suissebos province, Ecuador | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Atalaia butyroacae and Oenocarpus bataua | - |
| | colombiensis | Mejía, Galvão & Jurberg | 1999 | Totoro (20) | Cotayma, Colombia | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Atalaia butyroacae | Cytb, 16S, 18S |
| Rhodesius | marabeni | Souza et al. | 2016 | Marabá (21) | Pará, Brazil | N. C. B. Von Atzingen, M. B. Furtado UNESP | Dwellings (Marumurú Environmental Reserve) | Cytb |
| | nickii | Zhao, Galvão & Cai | 2021 | Santa Cruz, Santa Cruz (22) | Bolivia | Natural History Museum, UK | - | - |
| | melosi | Carcavallo, Rocha, Galvão & Jurberg | 2001 | Bragança (23) | Pará, Brazil | Rodolfo Carcavallo Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Maximiliana regina and Atalaia speciosa | - |
| | montenegroensis | Rosa et al. | 2012 | Monte Negro (24) | Rondonia, Brazil | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Orbignya phalerata | Cytb |
| | stali | Lent, Jurberg & Galvão | 1993 | Salobma (25) | Mato Grosso, Brazil | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Atalaia phalerata | Cytb, 16S, 18S |
| | zeledoni | Jurberg, Rocha & Galvão | 2009 | Arracaju (26) | Sergipe, Brazil | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | - | - |
| Genus | Species | Author | Year | Type locality | Distribution | Collection (Type) | Ecotope | DNA sequence |
|-------|---------|--------|------|---------------|--------------|------------------|---------|--------------|
| Triatoma | bahiensis | Sherlock & Serafim | 1967 | Ipuipuara (27) | Bahia, Brazil | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | - | Cytb |
| | baratai | Carcavallo & Jurberg | 2002 | Bonito (28) | Mato Grosso, Brazil | Rodolfo Carcavallo Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Near a cave | Cytb, COI, 16S |
| | bolivari | Carcavallo, Martínez & Pelaez | 1987 | Colima (29) | Jalisco, Mexico | Rodolfo Carcavallo Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | - | Cytb, ITS-2 |
| | boliviensis | Avendado, Espada, Gil, Asturizaga, Mamaní & Prieto | 2007 | Muecas (30) | La Paz, Bolivia | Colección Boliviana de Fauna del MNHN, Facultad de Ciencias Pura y Naturales de la Univ. Mayor de San Andrés, La Paz, Bolivia | Rocks | - |
| | brasiliensis | Martínez, Carcavallo & Pelaez | 1984 | Colima (31) | Jalisco, Mexico | Rodolfo Carcavallo Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | - | Cytb, ITS-2 |
| | brasiliensis macromelasoma | Galvão | 1956 | Petrolina (32) | Pernambuco, Brazil | Instituto Oswaldo Cruz Entomological Collection, Rio de Janeiro, Brazil | - | Cytb |
| | caraivalloi | Jurberg, Rocha & Lent | 1998 | Santana do Livramento (33) | Rio Grande do Sul, Brazil | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Under rocks | Cytb, COI, COII, 16S |
| | dominicana | Ponair | 2005 | La Toca Amber mine, Puerto Plata and Santiago (34) | Dominican Republic | Ponair Ambar Collection, Oregon State University | Ambar | - |
| | garciabesi | Carcavallo, Cichero, Martínez, Prosen & Ronderos | 1967 | Córdoba (35) | Argentina | Rodolfo Carcavallo Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | - | - |
| | gomeznunezi | Martínez, Carcavallo & Jurberg | 1994 | Puerto del Rayo (36) | Oaxaca, Mexico | Rodolfo Carcavallo Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Under rocks | - |
| | huchuetenanguensis | Lima-Cordón & Justi | 2019 | Huichuetenango (37) | Aldea Chamarro, Guatemala | Instituto Oswaldo Cruz Entomological Collection, Rio de Janeiro, Brazil | Domiciliary ecotopes | ITS-2 Cytb |
| | jatai | Gonçalves, Tevon-Neves, Santos-Mallet, Carbajal-de-la-Fuente & Lopes | 2013 | Fazenda Jatai (38) | Tocantins, Brazil | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Rock outcrops | - |
| | jauzeirensis | Costa & Felix | 2007 | Juazeirinha (39) | Bahia, Brazil | Instituto Oswaldo Cruz Entomological Collection, Rio de Janeiro, Brazil | - | Cytb, ITS-2 |
| | jurbergi | Carcavallo, Galvão & Lent | 1998 | Rondonópolis (40) | Mato Grosso, Brazil | Rodolfo Carcavallo Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | - | Cytb, COI, 16S |
| | khibi | Carcavallo, Jurberg & Galvão | 2001 | Nova Petrópolis (41) | Rio Grande do Sul, Brazil | Rodolfo Carcavallo Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Rock crevices | Cytb, COI, COII, 16S |
| | melanica | Neiva & Lent | 1941 | Espinosa (42) | Minas Gerais, Brazil | Instituto Oswaldo Cruz Entomological Collection, Rio de Janeiro, Brazil | - | Cytb |
| | mopan | Dorn, Justi & Dale | 2018 | Rio Frio cave (43) | Cayo, Belize | Instituto Oswaldo Cruz Entomological Collection, Rio de Janeiro, Brazil | Cave | ITS-2 Cytb |
| | pintodiasi | Jurberg, Cunha & Rocha | 2013 | Vila Nova do Sul (44) | Rio Grande do Sul, Brazil | Herman Lent Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Under rocks | - |
| | roai | Alevi et al. | 2020 | San Miguel (45) | Corrientes, Argentina | Dr. Jose Maria Soares Banta Triatominae Collection (CTUMSS) of the São Paulo State University | Fallen tree trunks, tree holes, bromeliads, palm trees, in opossum holes and in dry cacti, and domiciliary ecotopes | Cytb |
| | sherlocki | Papa, Jurberg, Carcavallo, Carqueira & Barata | 2002 | Santo Inácio (46) | Bahia, Brazil | Faculdade de Saúde Pública, Universidade de São Paulo, São Paulo, Brazil | Rocks | Cytb, COI, COII, 16S, 28S |
| | vandae | Carcavallo, Jurberg, Rocha, Galvão, Noireu & Lent | 2002 | Itiquiri (47) | Mato Grosso, Brazil | Rodolfo Carcavallo Collection, Instituto Oswaldo Cruz, Rio de Janeiro, Brazil | Stone walls | Cytb, COI, COII, 16S, 28S |

*: fossil species; **: revalidated after 1979.
almost inexistent in some of the endemic countries.\(^{(98)}\)

Another major obstacle is the interruption or reduction of *T. cruzi* transmission by native vectors.\(^{(99)}\) The precarious information system is also a barrier to a robust evaluation of the actual epidemiological scenario, mainly in Bolivia, Paraguay, and Mexico.\(^{(6)}\) In Brazil, a common problem is the lack of stable funds for vector control. Besides that, the focus to control Chagas disease is frequently weakened when other threats (e.g., dengue fever, Zika, Chikungunya, and yellow fever, and leishmaniosis) take place. Vector control strategies must be designed to overcome some of these problems, such as the Integrated Vector Management (IVM) - a worldwide trend.\(^{(7)}\)

Furthermore, there are difficulties in monitoring and controlling the vectors in hyperendemic areas like the Gran Chaco (Argentina) because of the high infestation indices. In these areas, the use of insecticides is extremely frequent, and resistance has already been de-
ected in *T. infestans*. More recently, localities highly infested by infected *T. brasiliensis* were also studied by Liliosso et al. raising new issues for the Northeast region, Brazil, since this species is recorded in five Brazilian states. Finally, even though there are no domiciliated species in the United States of America, an increasing number of autochthonous cases of Chagas disease has been noted, which is a matter of concern to the health authorities in that country.

Besides the new vectorial problems, it is important to mention the threats imposed by (i) the lack of maintenance of national programs using new technologies to monitor and prevent Chagas disease; (ii) the climate change and human activities constantly changing the natural environment; and (iii) the new species of triatomines being described. This evolving scenario requires a constant monitoring activity in the endemic countries for Chagas disease, as well as comprehensive educational programs. It is now suggested that some triatomine species are able to adapt to new environmental conditions, invade new areas, and generate new phenotypes, which also poses new challenges and questions for the understanding of vector-parasite interactions and controlling of the disease, and the *T. cruzi* transmission.

**In conclusion**

In conclusion, the 47 post-1979 triatomines described or revalidated do not seem to change the current epidemiological status of the Chagas disease, because most of them are strictly sylvatic (Table). In that list, there are only five exceptions, the first one is *T. juazeirensis*, which is very well-studied in the State of Bahia (Brazil) and frequently encountered inside houses and near forested areas; the second, also found in Bahia, is *T. sherlocki*, showing an incipient capacity for colonising domiciles. The third is *T. b. macrovellosa*, from Pernambuco State, where this vector is frequently found in the peri-domicile however, eventually it can be found infesting the domiciles. The fourth one is *T. rosai* which occupies a great variety of ecotopes in several areas of Argentina, Bolivia and Paraguay and the fifth one is *T. huehuetenangensis*, found naturally infected by *T. cruzi* in domestic ecotopes, being considered a potential important vector in Guatemala.

Despite the evidence that the great majority of the post-1979 revalidated or new species of triatomines are not able to change the classical epidemiologic scenario of the *T. cruzi* transmission, a great effort must be devoted aiming to improve the knowledge of the recently described species. For instance, most of them lack a characterisation of their molecular profiles and even the phylogenetic relationships and detailed ecological studies. These gaps in the knowledge of a variety of species impair a more complete understanding of their evolutionary history as well as the possibility of a comparative analysis of the ecology of the Triatominae.

According to the literature, the reports of WHO and the profile of the triatomines listed in the Table, the main acknowledged vectors like *T. infestans, R. prolixus, and T. dimidiata* are going to continue to be the great threats of the *T. cruzi* transmission to human populations. Several other species presenting a more reduced geographical distribution are going to persist infesting dwellings in several countries such as *T. brasiliensis* in northeastern Brazil and *P. geniculatus* in Colombia. In the face of the relative small epidemiologic importance of the majority of the 47 triatomines listed after Lent & Wygodzinsky, and the significant achievements in terms of modern technologies such as: diagnosis of the diseases, clinical evaluations, precise tools for molecular identification of the vector species, and the *T. cruzi* discrete typing units (DTUs) characterisation, modeling triatomines distribution throughout algorithm processes, the monitoring of vectors, and the educational programs are still the main actions to keep human populations free of Chagas disease.

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**AUTHORS’ CONTRIBUTION**

JC - Conceptualisation and writing of the first version; CD and CG - table content. All authors equally contributed to writing the versions, editing, and revising the text. The authors declare no conflict of interest concerning this manuscript.

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