*Am. J. Trop. Med. Hyg.*, 76(3), 2007, pp. 508–515


# PERIDOMICILARY HABITAT AND RISK FACTORS FOR *TRIATOMA* INFESTATION IN A RURAL COMMUNITY OF THE MEXICAN OCCIDENT

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*Abstract.* An examination of peridomestic area organization and triatomine collection in an endemic village for Chagas disease (Jalisco State) identified the habitat of *Triatoma longipennis* (dominant species) and the risk factors of peridomestic infestation. In 100 visited peridomestic areas, 369 structures (permanent, temporary, and natural) were submitted to active manual research of triatomines. Storage shelters had a higher infestation of *T. longipennis* than piles of brick and tile; baked clay material had higher degrees of infestation than others. The secondary species *Triatoma barberi* shares a wide range of peridomicilary habitats with *T. longipennis*. Peridomestic area infestation risks (evaluated with multivariate logistic regression analysis) are number of closed storage shelters, number of brick and tile piles, number of houses per peridomestic areas, and distance of peridomicile from natural environment. Because both species present great adaptability to different artificial habitats, strategies of control must involved improving the overall management of peridomestic areas to prevent stable colonization.

## INTRODUCTION

Mexico has long been considered as a non-endemic country for American trypanosomiasis (Chagas disease), but in the last decades, studies reported significant human seroprevalence rates, up to 32%, in various endemic regions.[1–4] Furthermore, Jalisco in the occident part of Mexico, is one of the states where a larger number of chagasic patients have been recognized.[5] A compilation of data collected in various states of Mexico has estimated the seropositivity of blood donors at 2.03%.[5] Moreover, clinical autochthonous cases of Chagas disease were diagnosed.[1,2,6–10] According to the estimation of the National Institute of Cardiology Ignacio Chavez in Mexico City, 5,000 people suffer from severe chronic chagasic cardiopathy in the country.[11] Thus, Chagas disease must be considered as the most important parasitic disease in Mexico.

Because of the partial efficacy of existing drugs and the absence of a vaccine, the control of triatomine vectors is the only way to control Chagas disease in various countries of South America. In Mexico, the existence of a wide diversity of sylvatic vector species hampers the efficacy of the current control strategy, mainly based on insecticide pulverization in infested dwellings.

More accurate information regarding Mexican triatomine behavior and risk factors for infestation of human dwellings is also needed. In the whole country, 33 species of triatomines have been described, of which 3 principal species were recorded in occidental and central states: *Triatoma longipennis* (Usinger, 1939), *Triatoma pallidipennis* (Stal, 1872), and *Triatoma picturata* (Usinger, 1939).[12,13] All three belong to the *phyllosoma* complex and are sylvatic vectors.[14,15] The presence of *T. longipennis* and *T. pallidipennis* have been documented in human dwellings in the states of Morelos, Jalisco, Colima, and Nayarit.[15–20] However, most of the *T. longipennis* specimens were collected outdoors, with scarce intradomicilary populations, except in the state of Colima, where the vector was mainly collected in intradomicilary areas.[20] Specimens were generally collected in brick or tile piles, chicken-coops, pigsties, and garbage dumps.

The epidemiologic importance of *T. longipennis* is supported by significant rates of human seroprevalence in areas where this vector is predominant and highly infected by *T. cruzi*.[21] Although *T. longipennis* is rarely observed indoors and is mainly present in peridomicilary compounds, even in Chagas disease transmission areas, information about *T. longipennis* behavior in peridomicilary areas is still limited, and risk factors for peridomicilary infestation are not known.[5,19]

In the occidental and central parts of Mexico, the species of the *phyllosoma* complex are the most abundant. Specimens of *Triatoma barberi,* a species that belongs to the *protracta* complex, are occasionally found indoors, but they are not very abundant in the villages. Their real epidemiologic significance for Chagas disease transmission is unknown.[14,18,19,22] However, in the southern part, *T. barberi* is a recognized domestic and peridomestic vector of *T. cruzi*.[23]

To better understand the peridomicilary infestation process by *T. longipennis*, a large entomologic and ethnographical survey was carried in Los Guerrero, a rural community in the Jalisco State (Mexico) where eight seropositive patients have been identified.[24] Inhabitants occasionally report the presence of vectors inside their houses. Of 1,821 specimens collected in peridomestic structures, *T. longipennis* was the dominant species (93.2% of adults) and *Triatoma barberi* was the second most prominent (6.6%). The study of the entomologic index was submitted elsewhere.[24] This study clarifies the nature of peridomicilary habitats of *T. longipennis* and further clarifies the risk factors of peridomestic area infestation.

## MATERIALS AND METHODS

**Study area.** This study was conducted in the “Valle de Ameca” at Los Guerrero village (20°26′564″ N, 103°53′872″ W, 1,295 mas), a rural community of the San Martin de Hidalgo municipality in Jalisco State, 90 km from Guadalajara city. This semi-arid region is characterized by a deciduous seasonal forest, which had been cleared to provide land for cultures around the village. Until now, the land was composed

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of numerous plots surrounded by rock pile walls, but mechanized agriculture is progressively changing the landscape toward open fields. The main crops are sugarcane (*Saccharum officinarum*), corn (*Zea mays*), and Maguey tequilero (*Agave tequilana*). The minimal and maximal annual average temperatures are 20°C and 28°C, respectively. Annual rainfall averages range from 987.6 to 1,349 mm; the dry season extends from October until June (data collected from Inegi organization: http://www.inegi.gov.mx/inegi/default.asp). Los Guerrero has a typical Mexican village architecture, in which streets cross at right angles and delimit large blocks of houses (*manzana*). No houses are spread around, and the whole village is surrounded by farmland. The village is composed of 314 dwellings, of which 151 (48%) were closed because people were living and working in other places. The total surface of the village is 79.8 acres. Seven hundred inhabitants were presently registered at the Sanitary Center. The village has never been sprayed with insecticides before this study. At the beginning of this study, the village was mapped, and all houses were plotted. One hundred occupied dwellings were randomly selected by an aleatory number assignment, visited, and mapped during the study.

**Definition of the peridomestic area and its structures.** Formerly, authors showed arbitrariness in discriminating peridomestic area boundaries. Some of them define the peridomestic area as the surface situated around living quarters with a radius of 10 to 100 m,[17,25] whereas others do not refer to space but to artificial structures and define the peridomestic area as all of the structures built by men around the domiciles: chicken-coops, storage shelters, pigsties, etc.[20,26] In this study, we define the peridomestic area (a private space organized and used by human around their domicile) as the full area around the house supporting permanent or temporary structures built and used by humans or by their domestic animals. When peridomestic areas were fenced, they were delimited by theses fences. Inside each peridomestic area, various items were recorded. They are referred to as follows. 1) Permanent (or built) structures (covered with a roof or not) are storage shelters, animal shelters, corrals, and chicken-coops. They have three different architectural patterns, with each one named in the local language: the closed ones have four walls and a door, the roofed-unclosed ones have three walls and no door, and the open ones have no walls. 2) Temporary (or mobile) structures are piles of wood, brick, tile, or various goods and ends. They can be displaced promptly but may remain in place for years. 3) Natural structures are trees (cultivated or not), rocks, and all kinds of cultivated plants. Trees where chicken rest fit in this class, as well as bird nests restricted to peridomestic trees. 4) Domestic animals are mammals, fowl, and birds. Mammals may be divided into small mammals (dog, cat, rabbit, and guinea pig) and farm mammals (goat, sheep, cow, pig, and horse). Birds kept inside cages were regarded as pets.

**Survey design.** From July to September 2003 (rainy season), a team of well-trained health workers, assisted by an entomologist, visited the peridomestic areas of the selected 100 dwellings, drew their limits, described their structures, interviewed their inhabitants, and captured triatomines. Permanent, temporary, and natural structures of each peridomestic area were recorded, numbered, plotted on the map, and described, following a standardized form. Density indexes (number of structures per 100 $m^2$) were determined for each kind of structure. Distances from each peridomiciliary structure to domicile were noted. A standard questionnaire was submitted to each householder concerning the number of inhabitants, age and origin, use of insecticide, and type and number of animals. Insects were collected by a direct manual search in the peridomestic area, using a flashlight but not a repellent product. The collection lasted the time necessary to visit all the available structures and to collect all the bugs present at each positive site. The captured insects were put in a labeled plastic flask with filter paper, using one flask per capture site. They were transported to the laboratory for morphologic identification according to the taxonomic keys of Lent and Wygodzinsky (1979) and for further processing (parasite infection rate, collection of wings, legs, and blood meals).[27]

**Data analysis.** Data were computerized and statistically analyzed using the Statview program. The dependent variables were the absence or presence of *T. longipennis,* in 1) peridomiciliary structures and 2) peridomestic areas. We considered a structure or a peridomestic area to be infested when at least one triatomine was captured. A total of seven independent variables were tested for association with the infestation of a given structure by $\chi^2$ tests and Fisher exact tests (all multinomial except distance from the house). A total of 28 independent variables were tested in multivariate analyses for association with peridomestic area infestation. Parts of the variables were computerized as binomial variables (15): presence or absence of chicken-coop, corral, storage shelter in adobe, cattle, horse, pig, dog, cat, rabbit, and fowl; presence or absence of mesquite (*Prosopis laevigata*) and guamúchil (*Pithecellobium dulce*); use of insecticide inside house and in peridomicile and presence of more than one house in the peridomicile. Other data were computerized as continuous variables (13): age of dwellers, number of high walls (> 2 m) limiting peridomicile, distance from peridomicile to the surrounding fields, surface area of the peridomicile and domiciles, length of fence made in baked clay (adobe or brick), numbers of permanent structures, temporary structures, storage shelters, brick piles, tile piles, wood piles, and fruit trees.

Finally, 12 variables were chosen for multivariate logistic regression analysis because their unadjusted association with the dependent variable was significant ($P < 0.05$). The 12 variables chosen for the model were as follows: 1) distance to the natural environment, 2) surface of the peridomestic area, 3) presence of more than one house (two houses may share the same peridomestic area), 4) number of closed and roofed-unclosed storage shelters, 5) number of brick and tile piles, 6) length of clay fences (adobe and brick), 7) presence in the peridomestic area of an adobe storage shelter, 8) presence of a mesquite tree, 9) presence of a fowl, 10) presence of a horse, 11) age of the inhabitant, and 12) use of insecticide inside domicile. All selected variables were put in the model, and variables with a high $P$ value were removed one by one until all the remaining variables were $P \leq 0.05$. The previously excluded variables were included one by one in the most parsimonious model and eventually retained according to their significance. Finally, only significant independent variables remained in the model.

## RESULTS

**Peridomestic area feature at Los Guerrero village.** In the village, the walls of the houses were made of brick (56%) or cement (35%), and 81% of them were plastered. All the peridomestic areas were located behind the houses, in the center of each large block of houses (*manzana*). They were clearly delimited by fences shared in common with neighboring dwellings. Most of them (67%) were fenced in with at least three to four high walls (> 2 m high), with the back wall of the house included. The surface areas of the peridomestic areas varied from 24 to 1,156 $m^2$ (average, 387.65 ± 258.5 $m^2$). The majority of peridomestic areas (54%) had one or two constructions and two or three piles of material. The proposed density indexes for permanent and temporary structures were 0.84/100 $m^2$ and 0.70/100 $m^2$, respectively. There was no peculiar spatial distribution of the different structures in the peridomestic area and at the locality level, except for the position of storage shelters that are against fence walls.

The vegetation was not densely implanted in the village and was mostly composed of small fruit trees. The overall density index for trees was 0.88/100 $m^2$. Trees were seldom used by fowl to rest or breed.

All the recorded domestic animals were present in the peridomestic area during the survey. They included a total of 400 mammals and 771 fowl. The majority of dwellings accommodated one or two dogs, one or two cats, and a few poultry (mean = 17 ± 11). Pigs (mean = 3 ± 1) were present in 21 houses, goats or sheep (8 ± 3) in 12 houses, cows (3 ± 1) in 15 houses, and horses in 16 houses. Only seven dwellings had rabbits. The density index was 0.54/100 $m^2$ for small mammals, 0.59/100 $m^2$ for farm mammals, and 1.98/100 $m^2$ for fowl. Rodent feces were frequently observed during the triatomine search. Fowl were left wandering on the whole peridomiciliary area, in neighboring peridomestic areas, and even in the street. They slept mainly in chicken-coops. Horses were generally kept in a large corral and had a roofed open structure to rest.

**Collection and peridomicilary habitats of triatomines.** Of 629 structures, 369 were visited. The other were not because they obviously had no hiding places for bugs (concrete walls of corrals), they were too large to be searched (high brick piles), or they were locked (closed storage shelters). The numbers of visited structures remained generally proportional to each type (Figure 1).

Among the 369 visited structures, 115 (31.2%) were infested with *T. longipennis* (1,690 specimens captured of which 75% were nymphs) and 20 (5.4%) were infested with *T. barberi* (120 specimens captured of which 62.5% were nymphs). The average number of infested sites per peridomestic area was 1.95 (range, 1–5). Figure 2 presents the distribution of the *T. longipennis*–positive sites (= structures) in the village. Small colonies were more abundant than large ones, and the number of structures with one or two specimens reached 30%. However, abundant colonies (≥ 60 insects) of *T. longipennis* were observed in five structures. It is worth noting that the infection rates of the two species are similar and reach 46% for the entire population (nymphs and adults).

Table 1 shows the features of the structures to which *T. longipennis* were significantly associated. Permanent structures were significantly more often infested than temporary ones ($P < 0.001$). However, the crowding index was not significantly different between the two groups. The main permanent structures were storage shelters, followed by corral and chicken-coops. They were all mainly built with bricks. The infestation rates did not differ significantly from one type of permanent structure to the other. However, the open structures (mainly tejaban and some corrals) were less infested (not significantly) than the closed or roofed-unclosed. The most abundant temporary structures were heaps of brick and tile, followed by firewood or timber piles and heaps of goods and ends. Piles of bricks and tiles were more often infested

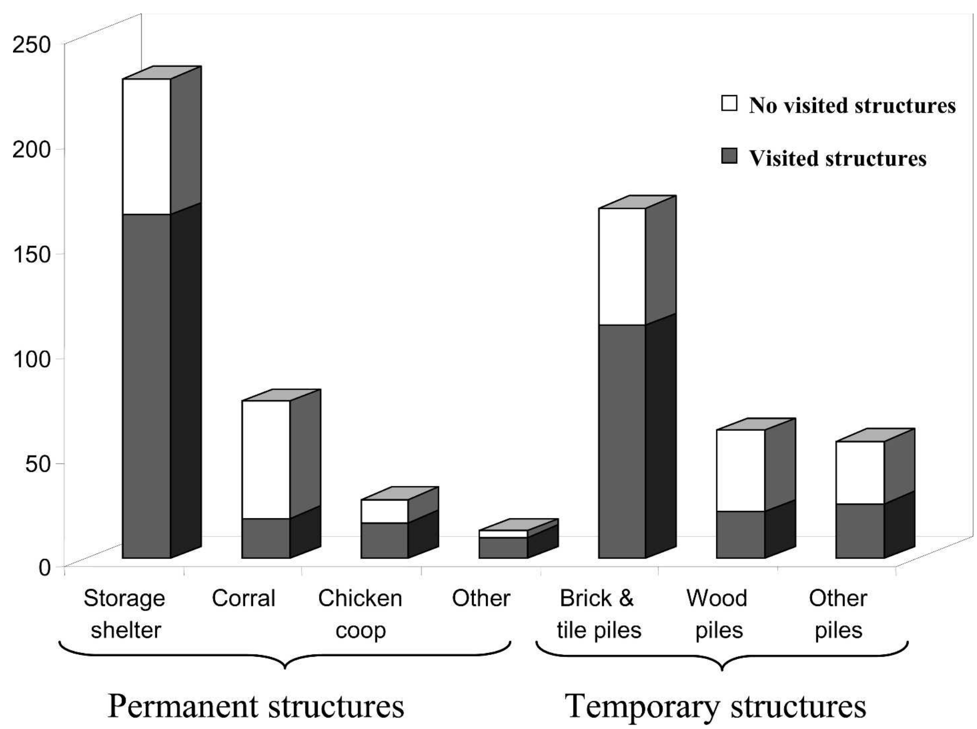


FIGURE 1. Numbers of existing visited and not visited structures in the peridomestic areas of Los Guerrero village (Jalisco state, Mexico) in July 2003.

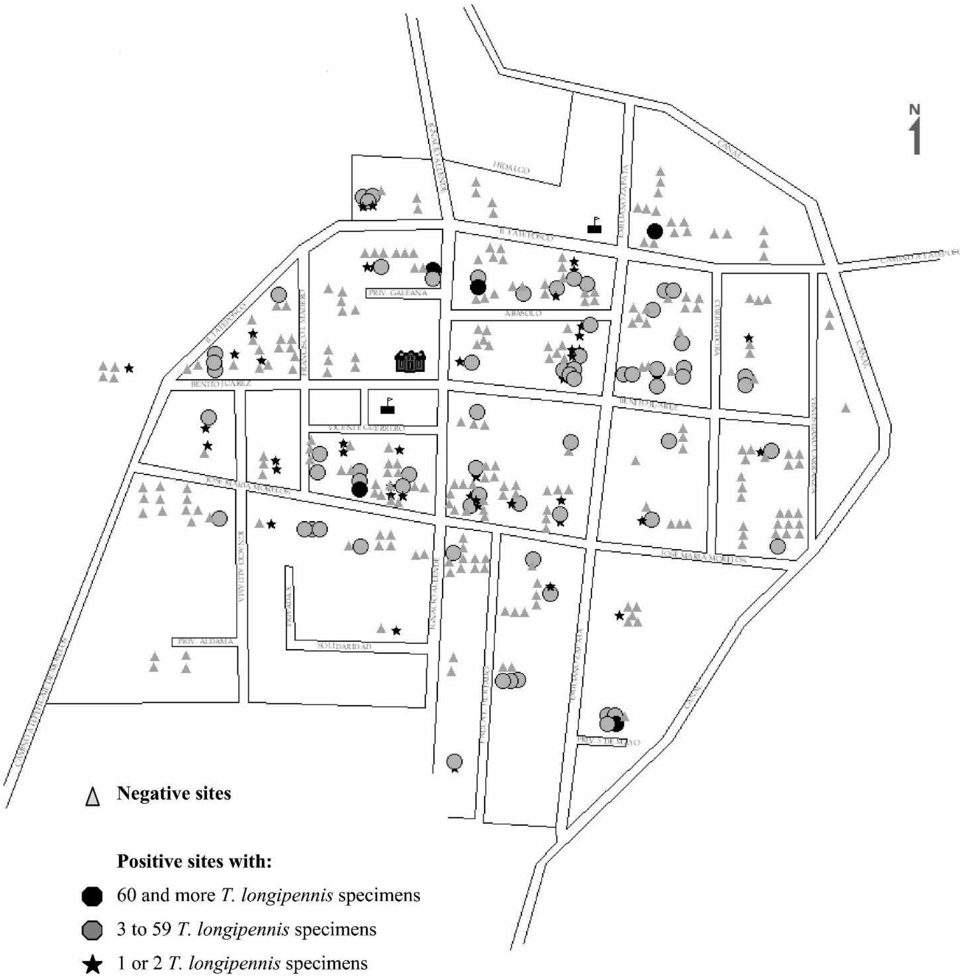


FIGURE 2. Distribution of the uninfested and infested sites by *T. longipennis,* the principal vector species, in Los Guerrero village. The number of insects per site ranged from 1 to 318: ★, sites with 1 or 2 insects; ○, 3–59 insects; ●, very large size colonies (60–318 insects); △, negative sites.

(not significantly) and significantly more densely infested ($P = 0.016$) than the piles of wood and various goods. On the whole, storage shelters were significantly more infested than piles of brick and tiles ($P < 0.01$), and none of the natural structures could represent a potential habitat for insects.

The insects were more often collected on baked clay material (adobe, brick, and tile) than on wooden and other materials ($P = 0.0012$). Moreover, *T. longipennis* was more often captured on brick walls (39/76) than in brick piles (19/72). The number of insects in each site was not associated with material. The six biggest colonies were captured in various types of habitats: 1) in a pile of bricks (in the open air) near which a dog was permanently attached (318 tritomines), 2) in a pile of bricks under an open storage shelter where a dog was also permanently attached (203 triatomines), 3) in a fire wood pile stored for a long time under a roofed-unclosed storage shelter (132 triatomines), 4) under big posts of wood in an open storage shelter (67 triatomines), 5) in a pile of goods and ends inside a closed storage shelter (63), and 6) in a pile of bricks placed in an open space (60). Therefore, whatever its favorite habitat is, *T. longipennis* is able to adapt to various types of materials and may build large colonies.

The presence of domestic mammals or poultry near a peridomicilary structure has no significant effects on its infestation with *T. longipennis* ($P = 0.15$). None of the observed colonies were associated with an animal except the two largest ones with dogs.

Twenty sites were infested with *T. barberi,* six of which were heavily infested (10–24). No statistical analysis was performed because of the small number of registered sites. Nevertheless, the features of peridomicilary habitats presented some trends. *T. barberi* was captured more often in storage shelters and on baked clay material. It was not associated with the presence of any animals, and it was not localized at a particular distance from the domicile. It was associated with *T. longipennis* in 17 sites, with a significant co-occurrence. Indeed, according to the frequencies of the infested sites by *T. longipennis* and *T. barberi* in the village, and the null hypothesis of absence of association (random co-occurrence) of the two species, the expected frequency of the sites with the two species was 0.016, corresponding to six sites. The $\chi^2$ test performed for observed and expected values gave a significant $P < 0.01$.

**Characteristics of the peridomestic areas associated with *T. longipennis* infestation.** A total of 60 peridomestic areas were infested with *T. longipennis* and 16 with *T. barberi.* Descriptive factors associated with *T. longipennis* infestation are shown in Tables 2 and 3 (binary and continuous variables,

TABLE 1
Features of the peridomicilary structures associated with *T. longipennis* infestation

| Descriptive variable | Number of structures | Percentage structures infested with *T. longipennis* (N) | Crowding index of *T. longipennis* (N) |
|---|---|---|---|
| Class of structure | | | |
| Permanent | 210 | 37.60 (79) | 13.000 ± 28.86 (1,027) |
| Temporary | 159 | 22.60 (36) | 18.42 ± 52.99 (663) |
| Total | 369 | 31.20 (115) | 14.70 ± 37.92 (1,690) |
| *P* value | | < 0.001 | 0.77 |
| Uses of permanent structures | | | |
| Storage shelter | 164 | 40.80 (67) | 13.88 ± 31.13 (930) |
| Corral | 19 | 36.80 (7) | 8.00 ± 8.92 (56) |
| Chicken-coop | 17 | 23.50 (4) | 10.00 ± 6.37 (40) |
| Other permanent* | 10 | 10.00 (1) | – |
| Total | 210 | 37.60 (79) | 13 ± 28.86 (1,027) |
| *P* value | | 0.37 | 0.29 |
| Architecture of storage shelters and corrals | | | |
| Closed | 54 | 35.18 (19) | 9.84 ± 15.91 (187) |
| Roofed-unclosed | 96 | 46.80 (45) | 9.29 ± 20.81 (418) |
| Open | 31 | 25.80 (8) | 41.50 ± 68.99 (332) |
| Total | 181 | 38.50 (72) | 13.01 ± 30.06 (937) |
| *P* value | | 0.08 | 0.36 |
| Type of temporary structures | | | |
| Brick and tile piles | 111 | 27.03 (30) | 21.63 ± 57.64 (649) |
| Wood and good | 48 | 12.5 (6) | 2.33 ± 3.26 (14) |
| Total | 159 | 22.6 (36) | 18.42 ± 52.99 (663) |
| *P* value | | 0.10 | 0.016 |
| Material of the capture site | | | |
| Baked-clay | 231 | 37.23 (86) | 12.74 ± 35.27 (1,096) |
| Wooden | 71 | 25.35 (18) | 16.22 ± 33.95 (292) |
| Other | 63 | 15.87 (10) | 30.10 ± 62.9 (301) |
| Total | 365 | 31.23 (114) | 14.82 ± 38.07 (1,689) |
| *P* value | | 0.001 | 0.65 |

* Not considered in statistical analysis.
Crowding index = number of triatomine per infested structure.
The presence of animal near the structure and the distance of the structure from the domicile were not significant ($P > 0.05$).

respectively). They relate to the central localization of the peridomestic areas (distance to field ≥ 200 m, $P < 0.0185$) and to the peridomestic area composition (number of storage shelters, numbers of brick and tile piles, number of houses in dwelling, length of fences made with brick or adobe, presence of an adobe storage shelter, and presence of fowl) and suggest a role of human habits on peridomestic area infestation (age of the inhabitant, use of insecticide in the house, and presence of horses, which is a mean of transport in Los Guerrero).

The results of the multiple logistic regression analyses of the peridomestic area infestation by *T. longipennis* on selected factors are shown in Table 4. After backward elimination, only four variables remained independently significant: number of closed and roofed-unclosed storage shelters, number of brick and tile piles, number of houses in the peridomestic area, and distance to the field ≥ 200 m. The other factors were not significant in the model.

## DISCUSSION

This study was done in a village where peridomestic areas are heavily infested with *T. longipennis* (60% of the peridomestic area and 31.2% of the peridomicilary structures) and, to a lesser degree, with *T. barberi* (16% of the peridomestic area and 5.4% of the peridomicilary structures). The higher infestation index observed in our study may be caused by a different methodology for triatomine search. We did not restrain the time for search, but instead used a search of tritomines in all potentially infested sites. Moreover, both species exhibited high rates of *T. cruzi* infections.

Although available information regarding the potential habitat of *T. longipennis* in peridomestic area is scarce, previous studies have already shown that the vector was regularly collected in brick and tile piles, chicken-coops, pigsties, and garbage dumps.[15,19] Our results are partly consistent with previous observations. At Los Guerrero, *T. longipennis* was also mainly collected inside the storage shelters (where garbage dumps are numerous), corrals, chicken-coop, and piles of brick and tiles. On the contrary, none of the pigsties were infested, because they were frequently built with low cement walls and left no hiding place for insects. The pigsty characteristics were probably different in the villages visited in previous works. This study is the first one in Mexico to focus on the peridomestic habitats of *T. longipennis* and to state the relative infestation rates of each structure. In the Los Guerrero context, *T. longipennis* was more often associated with permanent structures (storage shelters, corrals, chicken-coops) than with temporary ones and with storage shelters than with piles of brick and tile. The main material for both was clay, and they were both numerous. Closed (or roofed-unclosed) storage shelters provided quiet places and good shelter from wind and rain, whereas piles of material were more often exposed to bad weather. These results fit with previous data collected in the state of Colima indicating that triatomines of *phyllosoma* complex are mainly captured in shaded and dry areas of the peridomestic area.[20] However, this study in Los Guerrero was performed during the rainy season, and it is possible that results would be slightly different during the dry months. The survey also confirmed that *T. longipennis*, a terrestrial vector, occupies preferably mineral materials (brick, tile, adobe) present in the peridomestic area. However, the vector may build colonies in other materials (such as wood) and thus is able to adapt to new ecotopes in the peridomicilary context.

In Los Guerrero, the organization of human dwellings is quite homogeneous, and the majority of peridomestic areas harbor potential habitats for triatomines. Only four peridomestic areas had no storage shelters and no piles of brick and tile. Therefore, what are the risk factors that determine the infestation of a specific peridomestic area? Only two studies have analyzed the risk factors for peridomestic area triatomine infestation in Mexico. They both concern *T. pallidipennis*, another vector of the *phyllosoma* complex that was collected indoors and outdoors in the rural town of Chalcatzingo (Morelos State).[18,28] The risk factors for peridomicilary infestation related mainly to number of animals (rabbit, dog, cat) and the presence of junk piles. In Los Guerrero, the risk factors were slightly different. The bivariate analyses and the logistic regression model confirmed that the accumulation of storage shelters and piles of brick and tile in peridomicilary area were risk factors. Their presence in a peridomiciliary area increased by two the odds of being infested. Finally, the presence of more than one house in the peridomestic area also increased the odds of infestation by a factor of 4. It should be pointed out that the overall surface area of the habitat unit (domicile and peridomicile) was not significantly associated to the peridomestic area infestation and that the peridomestic areas with two or more houses did not significantly differ ($P > 0.1$) from those with one house in term of

TABLE 2
Results of bivariate analyses of associations with *T. longipennis* infestation in Los Guerrero peridomestic areas: binary descriptive variables

| | Absent in household | | Present in household | | |
|---|---|---|---|---|---|
| | *N* | Percent infested | *N* | Percent infested | *P* |
| Significant association | | | | | |
| Adobe storage shelter | 65 | 61.5 | 16 | 93.7 | 0.004 |
| Horse | 83 | 54.2 | 17 | 88.2 | 0.01 |
| Fowl | 56 | 27.2 | 44 | 72.7 | 0.02 |
| Insecticide spraying in house | 15 | 86.6 | 15 | 56.6 | 0.04 |
| Number of house ≥ 2 in peridomestic area | 76 | 53.9 | 24 | 79.1 | 0.03 |
| Distance to field ≥ 200 m | 66 | 51.5 | 34 | 76.5 | 0.018 |
| No significant association | | | | | |
| Corral | 74 | 60.8 | 24 | 54.1 | 0.63 |
| Chicken-coop | 73 | 56.1 | 25 | 68 | 0.34 |
| Dog | 29 | 51.7 | 71 | 63.3 | 0.37 |
| Cat | 70 | 58.5 | 30 | 63.3 | 0.82 |
| Cattle (goat, sheep, cow) | 65 | 56.9 | 35 | 65.7 | 0.52 |
| Pig | 85 | 61.2 | 15 | 53.3 | 0.58 |
| Rabbit | 93 | 59.1 | 7 | 71.4 | 0.70 |
| Mezquite | 57 | 54.4 | 28 | 75.0 | 0.10 |
| Guamuchil | 55 | 56.4 | 30 | 70.0 | 0.25 |
| Insecticide spraying in peridomestic area | 59 | 62.7 | 39 | 58.9 | 0.83 |

superficial area, animal numbers, number of permanent and temporary structures, and location in the village. The pile of brick or the closed shelter presented risks by themselves (they are good habitats for triatomine) but also by their accumulation (more shelters for insects and greater difficulty to search and eliminate them). These results fit with the fact that open structures are less infested than closed ones, as mentioned above. Dwellings located in the central part of the village (distance to field ≥ 200 m) were not associated with higher number of storage shelter, brick or tile piles, or number of houses in the peridomicile. However, their odds of being infested was three times higher than the dwelling located at < 200 m from the fields. We suggest that structural organization of the village plays a more important role in the infestation process than the role at each specific structure. This probably relates to microclimatic conditions, favorable for *T. longipennis*, which are not yet clearly elucidated.

Furthermore, there is no clear association of animal presence and animal numbers with peridomestic area infestation. However, the presence of rats was noted during the survey, and a first analysis in our laboratory indicated that the rat is the main blood-meal source of *T. longipennis* (≈40.5% of the identified blood-meal sources) in Los Guerrero village.[29] Rats seem to be an important host for *T. longipennis* and may easily hide in closed storage shelters, in huge piles of brick, and in overcrowded peridomiciles, where there are numerous places to hide.

Although this study provides no clear evidence for human activities playing a role on triatomine infestation, some factors such as the presence of horses and fowl or use of insecticides should be considered in further studies, focusing on dispersion of triatomines. Their importance may be occulted in this study, designed to analyze the risk factors of triatomine installation in peridomicilary areas.

In this study, it was not possible to identify the familiar peridomestic habitat of *T. barberi* because the number of infested sites was too small for statistics. Remarkably, this species was mainly collected with *T. longipennis* (sympatric

TABLE 3
Results of bivariate analyses of associations with *T. longipennis* infestation in Los Guerrero peridomestic areas: continuous descriptive variables

| | Non-infested (40 peridomestic areas) | | Infested (60 peridomestic areas | | |
|---|---|---|---|---|---|
| Descriptive variables | Mean (min-max) | SD | Mean (min-max) | SD | *P* |
| Significant association | | | | | |
| Surface area of peridomestic area ($m^2$) | 335.6 (24–1156) | 264.0 | 422.3 (53–1000) | 250.9 | < 0.05 |
| Permanent structures (Nb) | 2.15 (0–7) | 1.95 | 4 (0–12) | 2.7 | < 0.001 |
| Temporary structures (Nb) | 2.1 (0–6) | 1.42 | 3.4 (0–10) | 2.4 | < 0.01 |
| Storage shelter closed and roofed-unclosed (Nb) | 1.5 (0–3) | 1.1 | 2.4 (0–8) | 1.9 | < 0.0001 |
| Piles of clay material (Nb) | 1.05 (0–3) | 0.87 | 2.1 (0–8) | 1.9 | < 0.01 |
| Length of clay fences (m) | 32.3 (0–112) | 31.5 | 48.6 (0–135) | 33.5 | < 0.02 |
| Householder age (years) | 47 (26–77) | 14.8 | 60.6 (30–95) | 17.3 | < 0.001 |
| No significant association | | | | | |
| High wall around the peridomestic area (Nb) | 2.67 (0–4) | 1.23 | 2.92 (0–4) | 1.15 | 0.32 |
| Surface area of houses ($m^2$) | 109 (43–224) | 46.5 | 122.9 (36–269) | 54.6 | 0.25 |
| Open storage shelter (Nb) | 0.15 (0–1) | 0.362 | 0.37 (0–3) | 0.74 | 0.22 |
| Piles of wood (Nb) | 0.72 (0–3) | 0.78 | 0.7 (0–4) | 0.9 | 0.67 |
| Fruit trees (Nb) | 2.54 (0–20) | 4.1 | 2.25 (0–10) | 2.35 | 0.16 |

TABLE 4
Logistic regression of peridomestic area infestation by *T. longipennis* on peridomicilary descriptive variables

| Parameter | Parameter value | SE | *P* | OR (95% CI) |
|---|---|---|---|---|
| Intercept | –2.458 | 0.625 | < 0.0001 | 0.086 (0.025–0.29) |
| Distance to field ≥ 200 m | 1.343 | 0.553 | 0.0152 | 3.83 (1.30–11.33) |
| Number of closed and roofed-unclosed storage shelters | 0.715 | 0.214 | 0.0008 | 2.04 (1.34–3.11) |
| Number of bricks and tiles piles | 0.677 | 0.238 | 0.0044 | 1.97 (1.23–3.14) |
| Presence of two houses at least in peridomestic area | 1.445 | 0.653 | 0.0269 | 4.24 (1.18–15.24) |

$R^2$ = 0.298%; goodness of fit test, Pearson (4) $P < 0.0001$.

condition). Past reports have provided evidence of remarkable host specificity of the species belonging to the *protracta* complex.[30] Indeed, *T. barberi* was first reported around the house.[25] Later, this species was considered to be completely domiciliated because sylvatic specimens were not seen.[12] Last, a predictive model of geographical distribution of triatomines species showed that *T. barberi* presents a high overlapping location with *Neotoma mexicana*.[31] Also, specimens of this species were found in cornfields in Morelos state and in rocks (Oaxaca State).[28,31] During a survey in the Ameca valley (2002–2005), we captured 368 sylvatic triatomines (adults and nymphs) in rock pile boundary walls, but no *T. barberi* specimens were collected in this ecotope.[32] Whatever the primitive ecological niche of *T. barberi* is, these results showed its trend toward colonization of a diversity of peridomestic sites in sympatric conditions with other species. Moreover, previous studies in the village of Tepehuaje de Morelos situated 5 km far from Los Guerrero showed that intradomicilary colonization was absent.[16] The exact role of this secondary vector species in the transmission of Chagas disease remains to be determined.

The results offered in this paper provide some information about the peridomicilary ecotope of *T. longipennis*, point out accumulation of insect habitats as the main risk factor, suggests a probable role of the urban structure in the infestation process, confirms the trend of *T. barberi* toward colonization, and indicates that a better comprehension of the triatomine infestation process is related to better knowledge of peridomicilary ecology. As described for other triatomines species, further population genetics studies will contribute to increasing our understanding of the movement of populations (expansion, colonization) between ecotopes and different ecosystems.

Received November 16, 2005. Accepted for publication November 27, 2006.

Financial support: This study received financial support from the PAHO, Communicable Disease programme, TDR Grant ID A30442, and the Institut de Recherche pour le Développement (IRD).

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## REFERENCES

1. Tay J, Schenone H, Sanchez JT, Robert L, 1992. Current status of knowledge on Chagas' disease in the Mexican Republic. *Bol Chil Parasitol 47:* 43–53.
2. Dumonteil E, 1999. Update on Chagas' disease in Mexico. *Salud Publica Mex 41:* 322–327.
3. Mazariego-Arana MA, Monteon VM, Ballinas-Verdugo MA, Hernandez-Becerril N, Alejandre-Aguilar R, Reyes PA, 2001. Seroprevalence of human *Trypanosoma cruzi* infection in diferent geografic zones of Chiapas, Mexico. *Rev Soc Bras Med Trop 34:* 453–458.
4. Rangel-Flores H, Sanchez B, Mendoza-Duarte J, Barnabé C, Brenière SF, Ramos C, Espinoza B, 2001. Serologic and parasitologic demonstration of *Trypanosoma cruzi* infections in an urban area of central Mexico: Correlation with electrocardiographic alterations. *Am J Trop Med Hyg 65:* 887–895.
5. Cruz-Reyes A, Pickering-Lopez JM, 2005. Sobre la enfermedad de Chagas en México, con un enfoque biológico geográfico y socioeconómico. Available at http://www.ibiologia.unam.mx/pdf/noticias/CHAGMEX.pdf
6. Guzman Bracho C, Garcia Garcia L, Floriani Verdugo J, Guerrero Martinez S, Torres Cosme M, Ramirez Melgar C, Velasco Castrejon O, 1998. Risk of transmission of *Trypanosoma cruzi* by blood transfusion in Mexico. *Rev Panam Salud Publica 4:* 94–99.
7. Rangel H, Gatica R, Ramos C, 1998. Detection of antibodies against *Trypanosoma cruzi* in donors from a blood bank in Cuernavaca, Morelos, Mexico. *Arch Med Res 29:* 79–82.
8. Gloss G, Barrera MR, Monteon VM, Reyes PA, 1990. American trypanosomiasis and chronic Chagas cardiopathy at the "Ignacio Chaves" National Institute of Cardiology. *Arch Inst Cardiol Mex 60:* 261–266.
9. Gonzalez-Zambrano H, Amador Mena JE, Delgadillo Jaime CV, 1999. Regression of acute Chagas cardiopathy in an infant with a suspected transfusion infection. *Arch Inst Cardiol Mex 69:* 363–366.
10. Moreno Lopez RM, Sanchez Paredes L, Munoz Jimenez L, Monteon VM, Reyes Lopez PA, 2001. Chagasic cardiopathy in Tehuantepec. Preliminary report. *Arch Cardiol Mex 71:* 43–49.

11. Monteon-Padilla VM, Vargas-Alarcon G, Vallejo-Allende M, Reyes PA, 2002. Specific dilated myocardiopathy. Chronic chagasic cardiopathy at the National Institute of Cardiology Ignacio Chavez. *Arch Cardiol Mex 72:* S148–S152.
12. Zárate LG, Zárate RJ, 1985. A checklist of the Triatominae (Hemiptera, Reduviidae) of Mexico. *Inter J Entomol 61:* 257–271.
13. Carcavallo RU, Galindez Giron T, Jurberg J, Lent H, 1997. *Atlas of Chagas' Disease Vectors in the Americas.* Vol. 3. Rio de Janeiro: FIOCRUZ.
14. Magallón-Gastélum E, Magdaleno-Peñaloza NC, Kattahain-Duchateau G, Trujillo-Contreras F, Lozano-Kasten FJ, Hernández-Gutiérrez RJ, 1998. Distribución de los vectores de la enfermedad de Chagas (Hemiptera: Reduviidae: Triatominae), en el estado de Jalisco, México. *Rev Biomed 9:* 151–157.
15. Martinez-Ibarra JA, Barcenas-Ortega NM, Nogueda-Torres B, Alejandre-Aguilar R, Lino Rodriguez M, Magallón-Gastélum E, Lopez-Martinez V, Romero-Napoles J, 2001. Role of two *Triatoma* (Hemiptera: Reduviidae: Triatominae) species in the transmission of *Trypanosoma cruzi* (Kinetoplastida: Trypanosomatidae) to man in the west coast of Mexico. *Mem Inst Oswaldo Cruz 96:* 141–144.
16. Magallón-Gastélum E, Lozano-Kasten F, Margarita Soto Gutierrez M, Flores-Pérez A, Sánchez B, Espinoza B, Bosseno MF, Brenière SF, 2006. Epidemiological risk for *Trypanosoma cruzi* transmission by species of *Phyllosoma* complex in the occidental part of Mexico. *Acta Trop 97:* 331–338.
17. Bautista NL, Garcia-de-la-Torre GS, Haro-Artega I, Salazar Schettino PM, 1999. Importance of *Triatoma pallidipennis* (Hemiptera: Reduviidae) as a vector of *Trypanosoma cruzi* (*Kinetoplastida: Trypanosomatidae*) in the state of Morelos, Mexico, and possible Ecotopes. *J Med Entomol 36:* 233–235.
18. Enger KS, Ordonez R, Wilson ML, Ramsey JM, 2004. Evaluation of risk factors for rural infestation by *Triatoma pallidipennis* (Hemiptera: Triatominae), a Mexican vector of Chagas disease. *J Med Entomol 41:* 760–767.
19. Brenière SF, Pietrokovsky S, Gastelum EM, Bosseno MF, Soto MM, Ouaissi A, Kasten FL, Wisnivesky-Colli C, 2004. Feeding patterns of *Triatoma longipennis* Usinger (Hemiptera, Reduviidae) in peridomestic habitats of a rural community in Jalisco State, Mexico. *J Med Entomol 41:* 1015–1020.
20. Espinoza-Gomez F, Maldonado-Rodriguez A, Coll-Cardenas R, Hernandez-Suarez CM, Fernandez-Salas I, 2002. Presence of triatominae (Hemiptera, Reduviidae) and risk of transmission of Chagas disease in Colima, Mexico. *Mem Inst Oswaldo Cruz 97:* 25–30.
21. Trujillo-Contreras F, Yerenas MA, 1995. Serological follow-up of *Trypanosoma cruzi* infection from 1987 to 1994 in 32 counties of the State of Jalisco, Mexico: preliminary report. *Cad Saude Publica 11:* 501–505.
22. Cortes-Jimenez M, Nogueda-Torres B, Alejandre-Aguilar R, Isita-Tornell L, Ramirez-Moreno E, 1996. Frequency of triatomines infected with *Trypanosoma cruzi* collected in Cuernavaca city, Morelos, Mexico. *Rev Latin Microbiol 38:* 115–119.
23. Ramsey JM, Ordonez R, Cruz-Celis A, Alvear AL, Chavez V, Lopez R, Pintor JR, Gama F, Carrillo S, 2000. Distribution of domestic triatominae and stratification of Chagas disease transmission in Oaxaca, Mexico. *Med Vet Entomol 14:* 19–30.
24. Brenière SF, Bosseno MF, Magallón-Gastelúm E, Castillo Ruvalcaba EG, Soto Gutierrez M, Montaño Luna CE, Tejeda Basulto J, Mathieu-Daudé F, Walter A, Lozano-Kasten F, 2007. Peridomestic colonization of *Triatoma longipennis* (Hemiptera, Reduviidae) and *Triatoma barberi* (Hemiptera, Reduviidae) in a rural community with active transmission of *Trypanosoma cruzi* in Jalisco state, Mexico. *Acta Trop* 10.1016/j.actatropica.2007.02.007.
25. Almeida CE, Duarte R, Nascimento RG, Pacheco RS, Costa J, 2002. *Triatoma rubrovaria* (blanchard, 1843) (hemiptera, reduviidae, Triatominae)) II: trophic resources and ecological observations of five populations collected in the state of rio Grande do Sul, Brazil. *Mem Inst Oswaldo Cruz 97:* 1127–1131.
26. Cecere MC, Gurtler RE, Canale D, Chuit R, Cohen JE, 1997. The role of the peridomiciliary area in the elimination of *Triatoma infestans* from rural Argentine communities. *Rev Panam Salud Publica 1:* 273–279.
27. Lent H and Wygodzinsky P, 1979. Revision of the Triatomine Hemiptera: Reduviidae and their significance as vectors of Chagus disease. *Bull Am Museum of Nat Hist 163:* 125–520.
28. Ramsey JM, Alvear AL, Ordonez R, Munoz G, Garcia A, Lopez R, Leyva R, 2004. Risk factors associated with house infestation by the Chagas disease vector *Triatoma pallidipennis* in Cuernavaca metropolitan area, Mexico. *Med Vet Entomol 19:* 219–228.
29. Bosseno MF, Santos García L, Baunaure F, Magallón Gastélum E, Soto Gutierrez M, Lozano Kasten F, Dumonteil E, Brenière SF, 2006. Identification in triatomine vectors of feeding sources and *Trypanosoma cruzi* variants by heteroduplex assay and a multiplex miniexon polymerase chain reaction. *Am J Trop Med Hyg 74:* 303–305.
30. Ryckman RE, 1962. Biosystematics and hosts of the *Triatoma protracta* complex in North America (Hemiptera:Reduviidae) (Rodentia:Cricetidae). *Univ California Pub Entomol 27:* 93–240.
31. Peterson AT, Sanchez-Cordero V, Beard CB, Ramsey JM, 2002. Ecologic niche modeling and potential reservoirs for Chagas disease, Mexico. *Emerg Infec Dis 8:* 662–667.
32. Magallón-Gastélum E, Lozano-Kasten F, Bosseno MF, Cardenas-Contreras R, Ouaissi A, Brenière SF, 2004. Colonization of rock pile boundary walls in fields by sylvatic triatomines (Hemiptera: Reduviidae) in Jalisco State, Mexico. *J Med Entomol 41:* 484–488.