The Initial Success of The Chagas' Disease Control Program: Factors Contributing to *Triatomine* Infestation

O Sucesso Inicial do Programa de Controle da Doença de Chagas: Fatores Associados com a Infestação por Triatomíneos

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While the control of the major Chagas' disease vector Triatoma infestans *has been achieved in many endemic areas of Brazil, data from the inception of the control program in the* Triângulo Mineiro *(1976-79) suggest that re-infestation by triatomines occurs under certain favorable conditions. The percentage of houses infested in 500 communities of the* Triângulo Mineiro *region is compared for two years: 1976 and 1979, using linear regression models. Controlling for three major triatomine vectors, household crowding, house demolition and construction, and infested out-buildings are all independent covariates of house infestation in these communities. While several household factors have been suggested as correlates of infestation, the control program focuses on community-level reductions in infestation, but intra-community or regional comparisons have heretofore been unfeasible. Computerized data are becoming available to identify communities at high risk for re-infestation, and for targeting control-program activities.*

Keywords: *Chagas' Disease; Control;* Triatoma sp.*; Brasil*

INTRODUCTION

Chagas' disease is a parasitic disease caused by *Trypanosoma cruzi*, carried to humans by Triatoma (family Reduviidae) insects. It is endemic throughout Southern and Central America, affecting 16-17 million persons (Maurice & Pierce, 1987), or 8% of the Latin American population (Schofield, 1985). In Brazil the disease is estimated to account for 10% of deaths among adults aged 25 to 65 (Maurice & Pierce, 1987; Pereira, 1984). Ten percent of cases die in the acute phase; 40% will suffer chronic symptoms in prevalent cases (Schofield, 1985).

Long-term infection can lead to chronic myocarditis, congestive heart failure, cardiac arrhythmias, and even sudden death in approximately 20% of cases, often decades after initial infection. The disease, following an acute often asymptomatic phase of 1-2 months currently has no cure, and infection is life-long (Kirchhoff et al., 1987). Infection can be transmitted congenitally, and via blood transfusion (Grant et al., 1989). The latter is now the greatest threat in countries like Brazil (Dias et al., 1985; Kirchhoff et al., 1987; Grant et al., 1989).

The major public health measure available is to reduce the contact between humans and *T. cruzi*-bearing vectors through regular inspection of housing and application of insecticides. During 1975-77, Brazil undertook a massive national study of Chagas' disease prevalence and distribution. Simultaneously, the Ministry of Health (MS/Sucam) began to spray dwellings in high prevalence regions to control triatomine vectors. As of 1987, the program annually expended between 35-40 million U.S. dollars to reach some 2445 counties (MS/Sucam/World Bank, 1987).

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OBJECTIVES OF THE STUDY

This research examines data gathered by the control program in its early period, which may be useful in re-focusing spraying efforts in the future. Data were available for the *Triângulo Mineiro* region of the state of *Minas Gerais*, as a continuous record of the control program from 1976 to 1979 for all 500 localities sampled in the Region's 60 counties during the National Prevalence Survey (Camargo et al., 1984). While a few longitudinal studies have been undertaken in small rural communities, there has never been regional-level assessment of factors explaining variation in triatomine distribution and level of household infestation. Moreover, The *Triângulo* region, which borders the states of *São Paulo*, and *Goiás*, is a confluence region for three major insect vectors of the disease; *Triatoma infestans*, *Triatoma sordida*, and *Panstrongylus megistus*. This area has exhibited communities with some of the highest prevalence of Chagas' disease (Camargo et al., 1984).

Household crowding is a primary limiting factor on the carrying-capacity for household triatomine population (Schofield, 1980; Marsden et al., 1982; Piesman et al., 1983). However, early research findings are based on a few houses in a few small communities. Triatomines go through five stages before reaching adulthood, each requiring a blood meal for development. Positive associations between human crowding and both household-level prevalence (Mott et al., 1978) and incidence of the disease (Marsden et al., 1982; Piesman et al., 1983; Hoff et al., 1985), and with vector density has also been noted. Household crowding has not been examined for community infestation level, nor for its relevance to long-term control of infestation.

Community-level studies of the disease also indicate great loss of local rural population during relatively short study periods, in some cases as much as 10-12% per year (Marsden et al., 1982; Mota et al., 1990). This is most likely for persons involved in the migrant labor force (adolescents to about age 40, an age group which exhibits the highest prevalence of Chagas' infection) (Mota et al., 1990). Questions are frequently raised concerning migration effects on Chagas' and other endemic diseases in Brazil's expanding rural frontiers (Foratinni et al., 1971; Litvoc, 1979; Marques & Pinheiro, 1979; Marques, 1982; Haddock, 1979; Hoff et al., 1985; Bentham, 1988), as well as its growing urban areas (Pereira, 1984).

While migration cannot be studied directly using the control program's data, change in a local population can be assessed indirectly in two ways. First, the National Prevalence Survey asked whether the individuals residing in sampled households had been born in the locality or elsewhere. This allows a rough estimation of the proportion of a locality's 1976 adult population who were long-term residents.

Secondly, the control program's semestral housing census kept track of demolition of older housing, and replacement by newer housing. Regular housing change has also been noted in the literature, but has not been used in evaluating local-level success of the control program (Marsden et al., 1982; Mota et al., 1990). These particular aspects would have direct impact on household infestation as the length of time a dwelling is inhabited, and deteriorated condition are good predictors of its infestation level (Mott et al., 1978). Many researchers note the relationship between the poor quality of rural housing and high rates of prevalence of the disease and triatomine infestation (Zeledon & Rabinovich, 1981; De Raat, 1976; Marsden, 1981; Dias & Dias, 1982; Dias, 1985), whereas residential hygiene (Piesman et al., 1983) and general measures of individual wealth (Marsden et al., 1982) do not always show a direct relationship. It has been proposed that removal of older housing could reduce infestation if newer housing is of better quality (Julien-Laferrier et al., 1989), and is well maintained (Schofield & Marsden, 1982). Demolition of infested housing, however, might equally increase local-level infestation rate if these houses are not replaced. Shifts in the rates of new construction and demolished housing have never been explored in their relation to local household infestation in the literature.

This research explores 1) the role of household crowding, and 2) the independent contributions of construction and demolition of housing, in local rates of dwelling infestation at the beginning of the spray program in 1976 in 500 selected communities of the *Triângulo Mineiro* region. Then these factors are re-examined, once the program was in effect, for the same communities in 1979.

METHODS

During the mid-1970's, the Ministry of Health's Statistical Division devised a proportional sampling plan of enumerated localities throughout Brazil. Each locality was mapped, and baseline population counted during the control program's "geographic reconnaissance" phase, using a unique house enumeration system. Each state's sample for the prevalence survey was weighted to oversample small rural clusters of houses, especially aggregates smaller than 200 houses (Camargo et al., 1984).

The *Triângulo* region was one of the exceptional regions where the prevalence and geographic surveys coincided with the initiation of the spray program. Data have been merged for the 445 of the 500 total localities which meet this criteria, to include baseline disease prevalence, demographic, and house infestation information for the baseline year of the spray program in the area (1976). The model developed for initial locality infestation is then compared to that for 1979, wherein each locality had been inspected and sprayed for at least two years, and where data on community populations are still recorded.

Definition of Variables

The dependent variable used in these regression analyses is the percentage of a locality's inspected houses infested by triatomine insects. A small percentage difference may exist between the inspected versus total existing houses, where inspection teams may not have entered temporarily vacated houses, or others which were permanently boarded and closed (on average less than 10% of all houses). As infested annexes or outbuildings provide a residual vector population to re-infest dwellings, the ratio of infested annexes to total dwellings is also tested as a variable.

The community population totals were updated each semester the spray program visited until 1979, when enumeration of inhabitants ceased. A community-level indicator of crowding is estimated by dividing the number of total residents, by the number of inhabited houses per locality in each visitation period. In addition, the 1976 National Prevalence Survey asked residents from a strict protocol of pre-selected sampled households whether they had been born in their current location. Thus, the adult immigrant-to-locally born ratio provides an approximation of population influx in each locality. High and low migration locations are defined as those whose adult population over age 15 include more or less than 50% of immigrants, respectively.

Three other indicators of recent populational change in the community include: the total number of houses built or demolished in the previous semester, and the net total of existing houses in each visitation. In the baseline year (1976), these figures represent the houses torn down or newly constructed in the six months prior to the advent of the spray program. The rate of demolition is defined as the ratio of houses demolished in the the interim between visits, to those remaining in the current period. The rate of new construction is similarly defined each semester.

A rural-urban dichotomous variable uses locational categories from Sucam records and contrasts small and medium sized farms with villages, small towns and cities. This roughly coincides with clusters of over or under 250 houses. The proximity of a stream or low-land area is also indicated by a designation of the locality as one which is sprayed by the anti-malaria control program. Malarial areas also included some of the poorer housing in the region according to local Chagas' program officials.

All tested models for the level of dwelling infestation control for the presence of each of the three major triatomine vectors in a community, as well as the existence of more than one vector species in any period of time. The additional explanatory power of all other variables will be tested after these four are forced into a linear regression model. A weighted ordinary least-squared regression model is developed for each period (1976; 1979), using SAS regression modeling package programs. A backwards and forwards variable selection process evaluates the independent contribution of each variable, and of two-variable interaction terms when others are already entered in the model. Inclusion is tested by means of the partial F test at a .05 level of significance. The first recorded visit per locality is used for each of the two years of study.

RESULTS

The 1976 house infestation model: The overall rate for house (not including annex) infestation for the *Triângulo* region's sampled localities was 6.6% of all inspected houses in 1976. However, this ranges between 113 communities with no house infestation to some with over 60.0% of their houses infested. In developing the baseline 1976 model however, it became apparent that separate models were required due to significant interaction effects between predominant vector species, rates of house demolition and the proportion of immigrant adults, in areas which were or were not previously covered by the malaria control program.

In Table 1, initial 1976 house infestation in the 227 localities in anti-malaria program areas was most influenced by the vector *T. infestans* (which brings the ratio of infested/ total inspected houses to 16.7%). After *T.infestans*, *T. sordida* independently raises the infestation ratio another 10.5%, and *P. megistus* adds 5.9%, once the other two vectors were considered. More than one house vector per locality contributed a further 5.0%, as did the demolition of houses prior to the advent of the spraying program (for an additional 3.9%).

In contrast, *T. infestans* contributed to a lesser degree to house infestation in the 270 non-malaria program areas, infesting 11% of all inspected houses. Here *P. megistus* and *T.sordida* contributed equally (each over 7.0%), and multiple vectors' magnitude of effect was similar to that seen in malaria-program localities (3.8%).

TABLE 1. Regression Models for Household Triatomine Infestation by Localities Wich Where or Were Not Sprayed for Malaria Control; *Triângulo Mineiro*, 1976

Malaria-Spray Program Areas (N=227 localities, R-square=.28)		s.e.	T	p<
Intercept	-.005	.017		
Presence of:	.167	.023	7.26	.0001
T. infestans	.105	.021	4.80	.001
T. sordida	.059	.027	2.16	.03
P. megistus				
% Houses Demolished	.039	.014	2.73	.006
Multiple vector species	.050	.019	2.75	.006
Non-Malarial Areas (n=270 localities, R-square=.28)				
Intercept	.0002	.002		
Presence of:	.113	.021	5.43	.0001
T. infestans	.071	.016	4.35	.0001
T. sordida	.074	.013	5.50	.0001
P. megistus				
Multiple vector species	.038	.016	2.32	.02
Infested outbuilding/house ratio	.13	.06	2.19	.029

A high immigrant-to-locally born adult ratio, e.g. where over 50.0% of a locality's adults are not locally born, approached significance in non-malarial areas, but neither the immigration ratio nor house demolition ratio were retained, once prevalent insect vectors were forced into the model. Above all, house infestation in non-malaria areas is most affected by the ratio of infested outbuildings to households. This variable independently contributes 13% to the overall infestation level, a role nearly equal to that of *T. infestans*, even when the direct role of all vectors has been accounted for in the model.

The two regression models for malarial and non-malarial localities accounted for some 26.0-28.0% of the variance in house infestation levels in these respective areas. The average number of persons per household failed to enter either stratas' 1976 infestation model, once the three vectors and multiple vectors were included in the models. Univariate data corroborate the fact that the average household size varied little by malarial/non-malarial area or by rural-urban location, in 1976.

Few localities saw significant new construction of housing in 1976; most declined in total number of houses, particularly in rural areas. However, net growth of newer housing i.e. with a net increase of 15.0% or more was marginally associated with lower rates of house infestation in univariate analyses.

The 1979 post-control program model:

By 1979, the Chagas' control program reached all locations in the sample. However, data on the quantity or types of spray used per locality are not entered as independent variables in the second panel year model because: 1) there was a fixed formula for mixing BHC insecticide solution, and a standard protocol for spraying house interiors, which was followed by all teams in the region (Silveira, 1985); 2) Only a handful of localities were ever missed in their semestral spray cycle between 1976 and 1979 in this region; and 3) all infested houses and their environs per locality were sprayed in these early years (Marsden, 1981; Silveira, 1985). Thus, use of spraying activity variables results in severe problems of multi-collinearity and failure to interpret the models for 1979.

By 1979, 214 localities, or 48% were reportedly free of house infestation, up from 133 localities in 1976. House-infestation free locations are included in the 1979 model as they were in the 1976 model. In univariate analyses there are no significant differences in house-infestation free locations' average household size, nor their demolition rates in comparison to localities which remained house-infested. All had at least two full years of spraying. Those free of house infestation were likely to experience greater rates of new housing construction. This reflects the influence of certain urban locations which far surpassed many rural areas'net growth of housing and population.

T. infestans appeared in 14 localities (6.1%), *T. sordida* in 111 (48.1%), and *P.megistus* in 97 in 1979 (41.1%). The regional prevalence of house infestation drops from 6.6% of all inspected houses in 1976 to 2.5% of houses in 1979 (Table 2), a testimony to the early effectiveness of household spraying. In a model for 1979 house infestation, the role of *T. infestans* drops to roughly half the level seen four years earlier (accounting for 6.0% of all houses being infested). *P. megistus* replaces *T. sordida* as the second most prevalent house-infesting vector, adding a further 4.0% to infestation levels. *T. sordida* and multiple vectors, however, are not significant covariates in the overall *house* infestation model by 1979, but still play an important role in annex infestation.

While the rate of house demolition declined from a high annual rate of 11.3% (or roughly one out of ten existing houses) in 1976, to 5.7% by 1979, demolition still acts to increase house infestation rates in this period. In 1979, the ratio of infested outbuildings/houses also positively influences house infestation, as it did originally in the 1976 model for non-malarial localities. For the first time, however, the ratio of new-to-existing houses is positively associated with house infestation levels. This is in contrast to 1976 univariate data, which, though not statistically significant, suggested an inverse relationship

TABLE 2. Household Triatomine Infestation Levels: *Triângulo Mineiro* Region, 1976-79

	1976	1977	1978	1979
Household Data:				
% Of inspected houses which are infested:	6.6	3.6	2.4	2.5
% Homes demolished in prior year:	1.3	6.5	5.2	5.7
% Inspected houses which are sprayed:	18.3	11.3	9.8	9.8
% Total houses not inspected:	11.4	8.3	6.9	6.6
Mean household size:	4.02	3.55	3.48	3.50
% Growth (loss) of houses from prior period:	-6.6	-1.5	-.05	-1.4
Triatomine Data:				
% Localities with house-infestation:	55.0	39.6	33.5	30.8
% Localities with following predominant *house-infesting* vectors:				
T. infestans	26.0	18.6	10.9	6.1
T. sordida	48.0	38.9	48.7	48.1
P. megistus	26.0	42.2	36.6	41.1
% Localities with multiple house vectors:	19.8	12.5	8.7	7.0
Of the above, the second house vector is:				
T. infestans	40.2	57.0	60.3	61.3
T. sordida	38.0	35.0	27.9	29.0
P. megistus	14.1	5.2	11.8	9.7

TABLE 3. Regression Models for Household Triatomine Infestation Stratified by Mean Household Size: *Triângulo Mineiro*, 1979

Localities with a Mean of 3 or More Persons/House (n=283, R-square = .29)		s.e.	T	p<
Intercept	-.001	.005		
Presence of:	.023	.017	1.33	.18 NS
T. infestans	.012	.009	1.33	.18 NS
T. sordida	.039	.007	5.03	.0001
P. megistus				
% Demolished Houses	.018	.019	.93	.35 NS
% New Houses	.037	.029	1.3	.19 NS
Ratio Infested outbuildings/all houses	.40	.055	7.28	.0001
Localities with Less than 3 Persons/House (n=159, R = .54)				
Intercept	-.015	.005		
Presence of:	.127	.026	4.75	.0001
T. infestans	.036	.010	3.57	.0005
T. sordida	.044	.011	3.79	.0002
P. megistus				
% Demolished Houses	.135	.028	4.74	.0001
% New Houses	.32	.039	8.07	.0001
Ratio Infested outbuildings/all houses	.13	.050	-1.52	.131 NS

between net increases in new housing and lower levels of house infestation. Migrant-to-local inhabitant ratios were not available in 1979, but the net growth (loss) of houses per locality may serve as a proxy for population shifts in 1979, again principally occurring in urban locations.

However, in 1979 model interaction effects are again noted for house infestation, this time between vector species, demolition effects, and localities where average household size is three persons or more per dwelling, versus localities with a smaller average household size. Again, separate models are required to interpret house infestation in these two strata.

In the 283 localities (12 urban and 271 rural) which had an average household size of three or more persons in 1979, *T. infestans* and *T. sordida* no longer enter the house infestation model, nor do the rates of house demolition or new construction (Table 3). In fact, two variables, the presence of *P. megistus* and the ratio of infested outbuildings to houses, explain 30% of the variance in house infestation in these high household-size locations. Also most of the urban locations are included in this strata.

In contrast, the 159 localities (1 urban and 158 rural) where the average household size was less than three persons, all three major vectors were still significant, independent covariates of infestation. *T. infestans* still contributes three times the level of infestation in comparison to the other two triatomine species. However, in these low-household size localities, house demolition now contributes to infestation rates to a slightly greater degree than the presence of *T. infestans*. It is in these localities that the greater the ratio of new-to-existing housing, the greater the level of house infestation. This factor's independent contribution to house infestation level equals that of the combined effects of all three vector species and house demolition put together. The final 1979 model for low-household size localities, including the three vector species, house demolition, and new housing explained some 54.0% of the variance in house infestation.

DISCUSSION

At the onset of the control program, *T. infestans* infested houses at roughly twice the rate of the other two vectors. Its predominant role in malaria-program areas may reflect a preferred ecological niche, a natural route from its territory to the south, and/or a greater prevalence of low-quality (e.g. mud/stick) housing in which to dwell. Its dominance in house infestation agrees with community-level observations where prolific *T. infestans* colonies discourage competition from other species (Marsden et al., 1982). Overall, however, in 1976 *T. infestans* and *P. megistus* were found in equal numbers of localities, or 26.0% of the sample respectively.

House demolition also occurred at a greater rate in malarial areas, and it was only here that it became a significant covariate of infestation in remaining houses. At baseline, the role of house demolition was equivalent to that of having a second vector species operating in the locality. A greater dispersal of *T. infestans* due to demolition in malaria-program localities seems unlikely as an interaction term for these two variables was not significant.

Researchers suggest DDT use in anti-malarial program had little or no direct effect on triatomines (Marsden, 1981). However, the absence of outbuilding infestation effect on house infestation in malaria areas would be consistent with anecdotal information that anti-malarial spraying caused greater dispersal of house-loving triatomines away from human habitats. In any event, the anti-malaria program was successful, and it ceased in most locations by the next decade.

The available 1976 indicator of migration by location of birth may not adequately reflect recent, localized population changes. In the same vein, averaged household size varied little by rural-urban, or malarial/non-malarial areas in the baseline period. Finally, net gain in new housing rarely occurred, thus limiting sample power to detect an effect of this variable on house infestation. None of these variables reached significance when the type of vector was already included in the 1976 models.

By 1979, the triatomine infestion differences between malaria and non-malaria program areas diminish, whereas locations with small average household size appear to lose both housing and population, including one urban setting. While relatively greater ratios of new-to-existing housing appear in such communities, versus those with larger households, total available housing is still slightly decreasing, indicating construction is not even replacing the former housing supplies.

The independent roles of both demolition and new-to-old housing in these settings may be due to one or more behaviors. Triatomines may have been transported to new houses through re-used construction materials or in residents' belongings (Miles, 1976). More simply, demolition of houses may drive triatomines, especially *T. infestans*, to seek the human blood sources in both new and existing dwellings.

Areas with higher person per household densities may not have experienced an outflow of their population. Their rates of house demolition and construction are about one-tenth that of less-crowded household areas, consistent with stable or slow growing population, and a relatively constant supply of housing. For example, Marsden (1981) describes a town in *Goiás* state in which the absolute number of infested houses falls between 1975 and 1979 in the municipal seat, while the relative percentage of infested homes remained unchanged (or about 24.0%). A new highway brought added population growth, but produced little change in the total supply of housing. The average household size, on the other hand, grew from 5.5 to 6.7 persons.

In predominantly *P. megistus* infested areas of Brazil, Piesman and colleagues (1983) found 70.0% of a community's houses with 4 or more persons to be densely infested, in comparison to only 20.0% of houses with fewer residents. As *P. megistus* is a slower and more easily disrupted feeder than *T. infestans*, higher human densities would favor this vector (Schofield, 1985). In the *Triângulo* region, the more free-ranging *P. megistus* may have survived in less well-sprayed annexes to re-infest these houses (Dias, 1979). High rates of outbuilding infestation, and the latter's significant influence on house infestation in more crowded household areas are consistent with this interpretation.

CONCLUSIONS

This study explored the roles of human migration, household size, construction and demolition of dwellings, when controlling for major insect vectors, in explaining initial levels of house infestation in a large region of Minas Gerais state. Of these, only crowding had specifically been addressed in the Chagas' disease literature. The second goal was to determine whether these factors continued to influence house infestation, once the control program was underway, given changes in the vector densities and distributions.

Researchers have long noted the portability of insect vectors in human belongings (Miles, 1976; Dias, 1985), and the role of migration in re-establishing other endemic diseases in non-endemic areas (Marques & Pinheiro, 1979; Marques, 1982). Similar patterns have been suggested for Chagas' disease (Mott et al., 1990; Barrett, 1979; Zicker, 1989). However, data on localized population movement, or on household level changes are infeasible to monitor at the level of a national program.

In this study, the ratio of immigrant-to-locally born adults in the 1976 sample only approached significance in those areas in which house demolition occurred at a much slower pace, and where *T. infestans* was not as dominant a vector. The measure of migration available for 1976 may be too crude to detect major differences in infestation during the actual 1976 inspection visits. However, questions could be raised whether the relative role of human transport of triatomines in infesting dwellings increases when *T. infestans* no longer plays a major role, or when there is little disruption of triatomines' domestic habitat. Both aspects would be pertinent to the control program in fast-growing peri-urban locations, for example.

The positive relation between house demolition and infestation has been broached, but never directly evaluated in the literature. In this sample, the effect of demolition appears to be centered in communities with high periodic loss of housing, and null or negative replacement by new construction. In the 1979 sample, demolition effects were also most notable in areas where *T. infestans* still played a major role in house infestation. In fact, it is difficult to determine whether demolition and *T. infestans* infestation are causally inter-related, or whether these communities were simply losing both population and housing at that time. In contrast, communities dominated by *P. megistus* exhibited lower rates of demolition, which in part may explain why this factor was not a significant covariate in the models for such communities. Colonies of *P. megistus* are often smaller and more free-ranging in the household environs than those of *T. infestans*. Thus, the former's dispersal by demolition may simply make a lesser impact on neighboring houses, or alternatively may increase annex infestation instead.

The role of new construction has also not been addressed heretofore. Rates of new construction were fairly low in the 1976 sample, failed to result in any net gain in housing, and did not enter the 1976 models of house infestation. Three years later however, urban and some rural areas were experiencing greater rates of new home building. Again construction appears only to barely replace existing demolished homes, and its positive influence on house infestation would appear consistent with human transport of triatomines from old residences to the new.

Today *T. infestans* is well controlled in a majority of the regions sprayed by the program, where most communities exhibit less than 5% of households to be infested (Dias et al., 1985). The program now relies on local informants to report re-infestation in these communities, rather than on regularly scheduled inspections (Dias et al., 1985; Dias, 1986, 1988; WHO/SERWG, 1983). *T. infestans* is not totally eliminated however, and still occurred in outbuildings in the *Triângulo* region as late as 1985, and in houses in the northern part of the state (Dias et al., 1985).

Control of the more ecologically versatile *P. megistus* and *T. sordida*, particularly in outbuildings, has been less successful. This study confirms community-level observations (Dias, 1979; Marsden et al., 1982; Foratinni et al., 1971) where *P. megistus* emerges as the dominant house vector when *T. infestans* is eliminated, and the long-term infestation of outbuildings by *T. sordida* (Dias, 1979). Researchers have struggled to develop new mechanisms to retain the effectiveness of insecticides in the flimsy annex constructions (Dias, 1988; Tonn, 1980). Indeed, triatomines' ecologic versatility in shifting between domestic and sylvatic environments makes their long-term control especially problematic (Zeledon & Rabinovich, 1981).

The relative contribution of outbuilding infestation to dwelling infestation, apart from that explained by the presence of specific vector species, has not been examined on a regional level. This study confirms the expected role of infested outbuildings as an independent covariate, especially where non-*T. infestans* vectors begin to emerge. In one *Triângulo* region county, all three vectors occur in both rural and urban household annexes, during the period of 1978 to 1985, even when house infestation is no longer reported. This is particularly true for storage barns and poultry coops, which pose a particular danger given the ready transport of farm products between domestic environs and the kitchen, and between rural and urban settings (Fleming-Moran, unpublished ms.). As part of the control programs' educational efforts, local inhabitants are urged not to transport firewood, or farm produce into the home.

Finally, this study presents the first regional level confirmation of the association between household crowding and the percentage of infested houses in a community. Once more, as *T. infestans'* role diminishes, human factors may play a greater part in determining household infestation. Over the three year study period, the regions' average household size declines, but shifts in population also occur. Areas with an average household size of three or more persons were those with *P. megistus* as a dominant species. They also exhibited low growth in available housing, where housing demolition continues, and includes most of the 1979 urban sample, as well as many rural locations.

Given Brazil's highly mobile population, an endemic disease surveillance and control system needs to account for the effects of significant, if localized, shifts in population. This implies use of proxy variables to highlight population change. Brazil's unique collection of community specific data on total housing, new construction, and demolition by semester allows the potential to target specific localities at risk of re-infestation, that is, those with rapid changes in local housing. Such data are obviously important in the control of Chagas' disease, but may be useful in yellow fever and malaria surveillance as well. Brazil's Sucam house enumeration system makes such monitoring feasible.

These data further suggest house infestation occurs under certain conditions, such as human crowding, and shifts in triatomine vectors. As of 1979, local population estimates are no longer kept by the control program. Recent computerization of program records could facilitate the recapture of demographic information to pinpoint areas resistant to triatomine control, or those at high risk of re-infestation. During the shift from a "vertical" delivery mode of the control program to one which includes greater administration at the local level (Dias, 1986; 1988), local informants may also need to provide timely information on fluxes in community population, as well as reporting triatomine infestation. Testing these evaluative approaches will be important in providing needed data on long-term triatomine control, especially in expanding peri-urban areas and rural development projects.

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RESUMO

FLEMING-MORAN, M. **O Sucesso Inicial do Programa de Controle da Doença de Chagas: Fatores Associados com a Infestação por Triatomíneos**. Cad. Saúde Públ., Rio de Janeiro, 8 (4): 391-403, out/dez, 1992.

Embora tenha sido controlado o principal vetor da doença de Chagas — o *Triatoma infestans* — em muitas áreas endêmicas do Brasil, os dados do início do programa de controle referentes ao Triângulo Mineiro (1976-79) sugerem a ocorrência de reinfestação por triatomíneos sob determinadas condições favoráveis. A autora compara as taxas de infestação domiciliar em 500 comunidades da região do Triângulo Mineiro para os anos de 1976 e 1979, utilizando modelos de regressão linear. Controlando para os três principais vetores triatomíneos, são variáveis independentes da infestação domiciliar nessas comunidades o amontoamento intra-domiciliar, a demolição e construção de habitações e as construções anexas infestadas. Embora vários fatores

domiciliares tenham sido sugeridos como correlatos da infestação, o programa de controle se concentra nos índices comunitários de infestação, enquanto as comparações intracomunitárias e regionais, até agora, têm-se mostrado inviáveis. Os dados computadorizados estão-se tornando disponíveis na identificação de comunidades sob alto risco de infestação, assim como, na definição de estratégias e atividades para os programas.

Palavras-Chave: Doença de Chagas; Controle; *Triatoma sp.*; Brasil

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