Spatial pattern of reinfestation by *Triatoma infestans* in Chancaní, Argentina

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ABSTRACT: We examined the environmental correlates and the spatial pattern of infestation by *Triatoma infestans*, a vector of Chagas disease, in a rural area of Argentina five years following an insecticidal campaign. Patterns of infestation were identified in an entomological survey, as mapped with high-resolution satellite imagery and analyzed in a geographic information system. Logistic regression was used to relate infestation to observed household characteristics as well as the location and density of households. Location was the most significant predictor of infestation for domiciles. For peridomestic structures surrounding the domiciles, the combination of location and the presence/absence of goat pens was most significant. In considering any infestation, whether domiciliary or peridomestic, the combination of location, presence/absence of animal pens, and the type of household construction were found to be most significant. Using these statistical relationships to back-classify the field data resulted in accuracies between 85% and 87%. A map of infestation probability for the town of Chancaní was developed from the logistic regression. ***Journal of Vector Ecology* 31 (1): 17-28. 2006.**

Keyword Index: Triatoma infestans, Chagas disease, *Triatoma infestans*, remote sensing, geographic information systems.

INTRODUCTION

In the Southern Cone region of South America, *Triatoma infestans* (Klug 1834) (Heteroptera, Reduviidae) is the main vector of *Trypanosoma cruzi* (Kinetoplastida, Trypanosomatidae), the etiological agent of Chagas disease. Chagas disease affects approximately 16–18 million people from Mexico through Central and South America (CDC 1999). *T. infestans* is distributed from southern Perú and Pernambuco in Brazil to southern Argentina and Chile. *T. infestans* is infected initially by feeding on infected humans or animals. Human infection arises from self-inoculation by feces from infected insects, either through cuts (e.g. Triatomid bite), eyes, or mouth.

T. infestans is characterized by its high level of adaptation to human dwellings (Rabinovich 1972) and is found almost exclusively in domiciliary and peridomestic environments (Avalos 1965). Several factors influence the presence of the species including environmental cleanliness, number of individuals living in the household, and the presence of dogs, cats, or other animals in or near the house. Another important variable is nesting habitat for the insects, which often is provided in thatch, mud, and adobe structures. In Argentina, *T. infestans* has been found from the northern border in Jujuy province to Chubut in the south. The species is found in the wild around Cochabamba, Bolivia (Dujardin et al. 1987, Bermudez et al. 1993), and exceptionally elsewhere (Lent and Wygodzinsky 1979). High mountain ranges and the marine coast are free of the insects (Lent and Wygodzinsky 1979, Canale and Carcavallo 1985) *T. infestans* can produce two generations per year in Brazil (Schofield 1980) but only one in the semiarid region of Argentina due to cold winters (Gorla and Schofield 1985). Triatomides are hematophagous, feeding on mammals and birds. The profile of domiciliary populations of *T. infestans* in Argentina shows that its main feeding sources are human beings and domestic animals (dogs and cats) (Wisnivesky-Colli 1987, Gürtler et al. 1997). *T. infestans* typically has high population densities in dwellings that have not been treated with insecticides, maintaining similar population sizes from year to year. Domestic (domicile and peridomestic) populations of triatomines are controlled mainly through application of the insecticide piretrine (Gualtieri et al. 1984, Segura et al. 1999).

The rural town of Chancaní (31.41°S, 65.46°W, 380m ASL) has a population of approximately 400 and is located in the province of Cordoba, Argentina, 121 km west of the city of Cordoba (Figure 1). The nearest location with long term climate records (1961-1990) is the town of Villa Dolores, approximately 60 km to the south and at a somewhat higher altitude (569 m ASL). Monthly minimum/maximum temperatures in Villa Dolores for January (summer) are 18°C/32°C, and for June (winter) are 5°C/18°C. Annual precipitation is 610 mm, with the majority occurring during the summer months. The local economy is based on small-scale agriculture. The geographical setting and construction methods in Chancaní (and other rural areas of north-central Argentina) are associated with subsistence-level livestock production (mainly goat).

Approximately half of the homes in Chancaní are constructed of adobe (mud/grass) bricks with thatch roofing that is made of layers of sticks and mud with grasses opportunistically established on the upper surface. This type of construction can easily provide shelter for *T. infestans*. In this paper we refer to this construction as thatched, since the use of adobe construction for walls corresponded quite closely to the presence of thatched roofs, and the thatched roofs provided the predominant shelter for *T. infestans*. To help control *T. infestans* and Chagas disease, the Argentinean Ministry of Health funded the application of insecticide to all domestic units in Chancaní, meaning all human bedrooms (domicile) plus any annexed buildings (peridomicile), four times between 1971 and 2001. In 2001 all domestic sites were sprayed with 2.5% SC deltamethrin (K-Othrina, Agrevo, Buenos Aires, at 25 mg a.i./m^2) applied with manual sprayer pumps of 5 L capacity with an application lance fitted with a Teejet 8002 or similar nozzle. The spraying method was the same in 1996, using Deltametrine® as the insecticide. Following the 1996 campaign, entomological surveillance was initiated, but no insecticide was provided to the community or municipal agents for ongoing eradication.

The entomological data used in this study corresponds to field surveys performed in conjunction with insecticidal treatments in January and February of 2001. Here we have combined the results of the 2001 entomological survey in Chancaní with satellite imagery for analysis in a geographic information system to identify patterns of infestation. Our goal was to assess the dependence of infestation by *T. infestans* on the location, housing density, and other selected attributes of households five years after the 1996 insecticidal campaign.

MATERIALS AND METHODS

During the 2001 field survey, all 117 residences in the Chancaní area were examined prior to the application of insecticide, and a variety of demographic data was collected for each household. The survey was performed by experienced field personnel from the Coordinación Nacional de Control de Vectores. Households and peridomestic structures were inspected by the time/hour method (Chuit et al. 1992) for evidence of infestation. Infestation was taken to mean the capture of at least one live *T. infestans* at a given site. In addition, field personnel identified cases where there were clear signs of *T. infestans* being present, but none captured. These signs included the presence of triatominae egg or exuvia, or triatomine fecal smears in the structure. *T. infestans* was the only triatomine species encountered in the field survey. The infestation index for *T. infestans* was 33.3 in domestic units (DU, the inhabited domicile plus peridomestic structures within 250 m). Peridomestic structures surveyed within the 250 m radius included bathrooms, food deposits, or pens for horses, chickens, pigs, goats, or cows. Breaking the infestation index down, 13.5% of the domestic units had live captures within the domicile, with an additional 3.5% having just signs of infestation in the domicile, and the remaining 16% having *T. infestans* just in surrounding peridomestic structures. For the study presented here, those cases which were coded as having visible signs of infestation were treated as infested (domestic versus peridomestic occurrence kept separate).

A number of conditions in the domiciliary and peridomestic structures were recorded during the 2001 field survey, including the type of roof and wall construction (thatch, zinc, or cement) of residential structures. Roof type was found to be an excellent indicator of the general susceptibility of different construction methods to infestation. Diagrams that indicated the relationship of sleeping quarters to the rest of the structure and the type (poultry, goat, pig, rabbit, horse) and location of animal pens in the peridomestic environment were made of each household during the 2001 survey. The number of occupants in the household was also recorded. Some of the household characteristics that were noted in the

Figure 1. Location of Chancaní, Argentina.

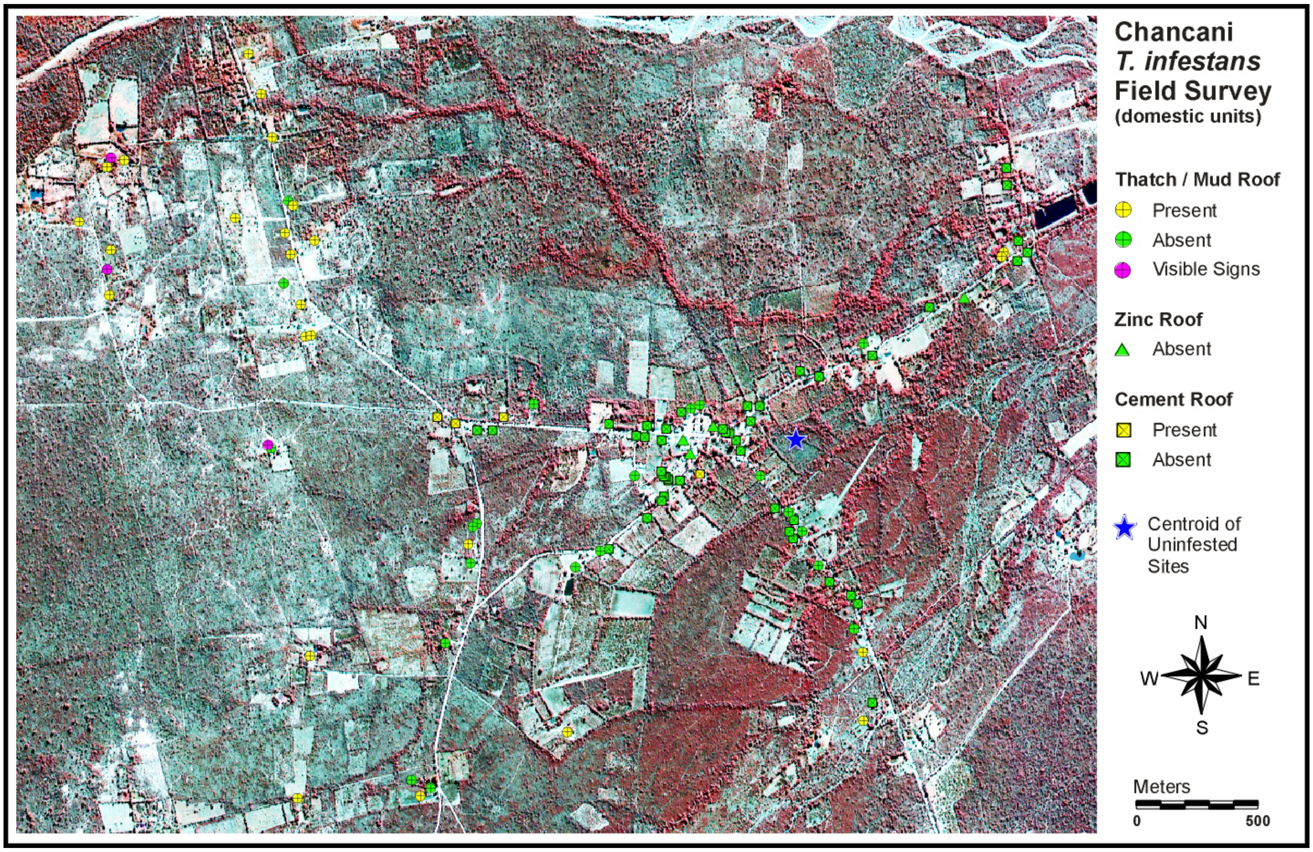

Figure 2. Infestation of *T. infestans* in Chancaní during 2001 survey.

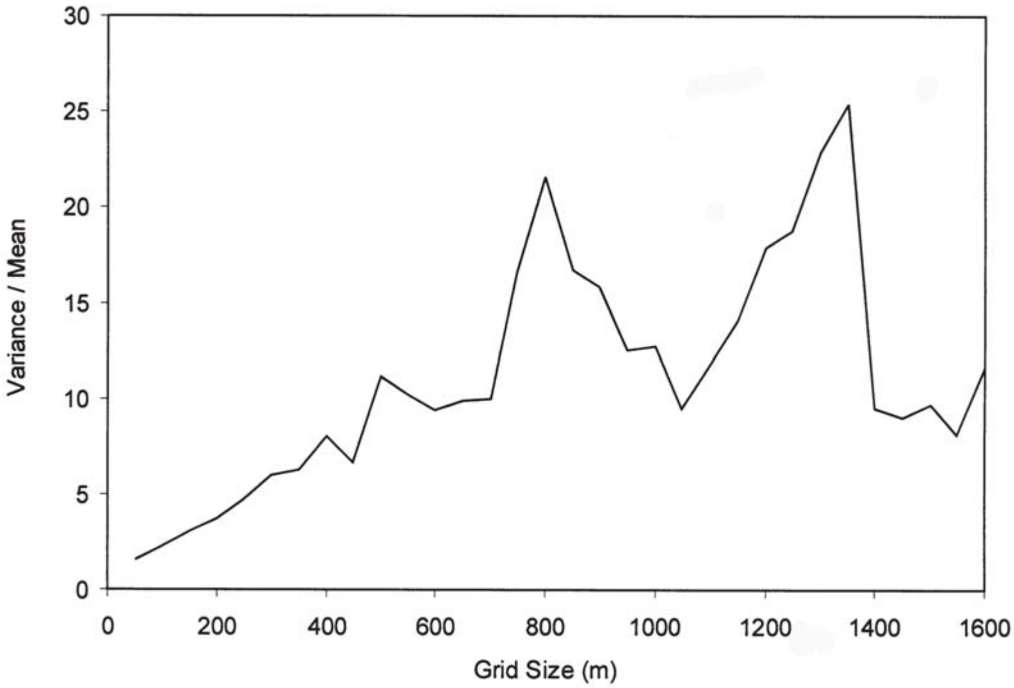

Figure 3. Variance/mean for housing density versus grid size.

survey were not common enough to warrant analysis, and these were removed or aggregated in this analysis (e.g. only three households had horses). The field survey variables used to characterize the household environment were:

1. *Roof*: 1 for thatched structures, 0 otherwise;
2. *Kitchen*: 1 if cooking area in same structure as bedrooms, 0 otherwise;
3. *Bedrooms*: number of bedrooms in the household;
4. *Occupants*: number of occupants in household;
5. *Poultry*: 1 if poultry pens in proximity to household, else 0;
6. *Goats*: 1 if goat pens in proximity to household, else 0;
7. *Pigs*: 1 if pig pens in proximity to household, else 0; and
8. *Animals*: 1 if there were any animal pens in proximity to household, else 0.

At the time of the 2001 survey, field personnel drew a map of the study area and assigned each residence a unique numeric identifier. While this sketch was sufficient for relocating homesteads in future visits, the map included large geometric distortions and simplifications that made quantitative geographical measurements impossible. A revisit of all 117 households to collect detailed spatial coordinates with a global positioning system (GPS) receiver was not feasible, but we were able to obtain a very high-resolution satellite image of the study area that the U.S. National Aeronautics and Space Administration (NASA) had acquired from Space Imaging Inc. This imagery provided accurate spatial information to supplement the field survey. The satellite imagery was from the IKONOS sensor, which collects multispectral imagery in four wavelength ranges (blue, green, red, near infrared) with a spatial resolution of 4 m. The IKONOS sensor also collects a panchromatic image with 1 m spatial resolution. The IKONOS image of the Chancaní study area was acquired on June 19, 2001, and was provided in the Universal Transverse Mercator projection (Zone 20, WGS84 datum). Individual residential structures were easily identified in the 1 m resolution image. Using image processing software (ENVI, Version 3.4; Research Systems, Inc.), we identified the households coded in the field sketch map on the planimetrically accurate satellite image and recorded their map coordinates. We then exported the household coordinates to ArcView geographic information system (GIS) software (Version 3.2; Environmental Systems Research Institute) and linked these coordinates with field data from the 2001 entomological survey.

Of the 117 households in Chancaní, 102 were included in this study. Field data was not collected for two uninhabited households; two households could not be located confidently in the satellite image, and 12 were clustered in a region that fell outside of the western boundary of the satellite image. In some cases, multiple structures were present on a single residential property. For these, a subjective choice was made as to which structure represented the household. Positional uncertainty associated with these decisions was much less than the typical inter-household distance in the study area and should have a negligible impact on this analysis. The closest neighboring village to Chancaní is 30 km away, and there are relatively few interactions that would be expected to result with transportation of *T. infestans* between the two towns.

Figure 2 presents the location, roof type, and infestation status of each household in the study area, overlain on a false-color infrared image from IKONOS (4 m resolution). This type of image emphasizes vegetation patterns with abundant, healthy vegetation appearing in red. A general pattern of infestation is apparent in Figure 2, in which the more densely populated town center remains relatively free from infestation while outlying areas have increasing prevalence. To some degree, this radial pattern may be attributable to a preponderance of modern construction methods in the town center. However, thatched structures also are infested much less frequently in the core of this radial pattern. The following additional variables were calculated from the GIS database to characterize the spatial dependence of infested households:

9. *Distance*: radial distance of household from center of the least infested area (meters),
10. *Neighbor*: distance to the nearest neighboring household (meters), and
11. *Density*: the number of households occurring within a selected search radius.

The center-point coordinates (centroid) for calculating the *Distance* variable was determined by taking the average position of all households that showed no signs of infestation in the domicile or peridomestic structures (Figure 2). The *Neighbor* and *Density* variables indicated housing density.

Table 1. Significance of individual variables.

Variable	**Peridomestic**	**Domicile**	**Domestic Unit**
Roof	0.00252	0.00004	< 0.00001
Occupants	0.66456	0.00853	0.04366
Kitchen	0.00931	0.00133	0.00156
Dining	0.45046	0.14040	0.20419
Bedrooms	0.52984	0.71746	0.85192
Poultry	0.73905	0.65072	0.67331
Goats	0.00001	0.00602	< 0.00001
Pigs	0.15626	0.28350	0.24109
Animals	0.01336	0.40896	0.00726
Distance	< 0.00001	< 0.00001	< 0.00001
Neighbor	0.00233	0.00713	0.00059
Density	0.00108	0.00225	< 0.00001

Neighbor provided a simple index of local housing density based on distance to the nearest neighboring household. However, the density of features measured in a region is inherently tied to a chosen scale of analysis (Getis and Franklin 1987). Colloquially, at a fine scale of analysis one might not see the forest for the trees, while at a coarser scale, features might be blurred together in ways that obscure actual relationships. This scale-dependence has two important consequences for the *Neighbor* variable. First, even within a region of relatively consistent housing density, there may be significant variability in the distance between individual households since houses in Chancaní are not spaced uniformly. Second, if the dispersal distance of the insects is larger than the distance between households, threshold densities to which the insects respond may not be related to conditions in the immediate neighborhood of a single household. The *Density* variable addressed both these concerns more directly. In order to determine the appropriate neighborhood for calculating housing density, the study area was overlain with geographical grids of varying size, and the variance to mean ratio was calculated for the number of households per grid cell at each grid size. The variance to mean ratio for counts within grids is an indicator of the spatial pattern of point features (i.e. households), with values greater than 1 indicating clustering, values near 1 indicating randomness, and values less than 1 indicating uniformity (Boots and Getis 1988). The search radius for calculating housing density was based on the grid size that best identified the inherent spatial clustering of households. When overlaying grids on a collection of clustered points, resulting calculations may be sensitive to the position of the grid relative to the underlying pattern. To minimize this effect, the ratio was calculated five times for each grid size, each time offsetting the geographical position of the grid to the west and north by 10% of the grid cell size. The mean of the five ratios for each grid size was used in this analysis.

Statistical analyses were performed for infestations in 1) domiciles, 2) peridomestic structures, and 3) entire domestic units (domicile and/or peridomestic structures). Predictive variables were assessed using logistic regression with the general linear model routine in S-Plus (*glm*) and specifying the binomial link function. Logistic regression allows prediction of a binary variable (i.e. infested or not) from a mix of categorical and continuous measures by solving for y = $e^x / (1+e^x)$, where x is the linear combination of the independent variables (Hosmer and Lemeshow 1989). The resulting estimates range between 0.0 and 1.0 in a manner that may be related intuitively to the probability of infestation. Variable selection was performed using Efroymson's stepwise method (Miller 1990), with selected variables requiring a *P*-value less than 0.05. Efroymson's method is a forward selection procedure that assesses partial correlations within the selected set at each step to determine whether any previously selected variables should be dropped. The *predict* function in S-Plus was used to derive fitted values for the samples. The spread of fitted values for infested versus uninfested samples were then plotted, and the percent of correctly classified samples were calculated. Type I (omission) and Type II (commission) error rates were also calculated. An example was then developed of generating an infestation probability map from the logistic regression.

RESULTS

Figure 3 plots the variance to mean ratio for households versus grid size in order to identify the most informative spatial scale for calculating housing density. The two dominant peaks in Figure 3 corresponded to clustering in household density at a more local (800 m) versus broader scale (1,350 m). While the second peak was somewhat larger in magnitude, it was more representative of the broad pattern of town center versus outlying regions, while the peak at 800 m was more sensitive to local variability. *Density* also became increasingly correlated with the *Distance* variable as grid cell size increased, reaching -0.86 at 1,350 m. Based on this, a search radius of 400 m (half the 800 m grid spacing) was selected for the calculation of *Density* in subsequent analyses.

Table 1 presents the significance of each independent variable individually predicting infestation status. For peridomestic structures, the significant individual predictors ($P < 0.05$) were *Distance*, *Goats*, *Neighbor*, *Density*, *Roof*, *Kitchen*, and *Animals* (descending order). For domiciles, *Distance*, *Roof*, *Kitchen*, *Goats*, *Density*, *Neighbor*, and *Occupants* were individually significant. For the entire domestic unit, *Distance*, *Roof*, *Goats*, *Density*, *Neighbor*, *Kitchen*, *Animals*, and *Occupants* were individually significant. Table 2 presents cross-correlations between the independent variables. As would be expected, there were strong correlations between the superset *Animals*, and some of the specific types of animal pens. Beyond this, there were strong cross-correlations between *Distance*, *Density*, and *Roof*, as was visually apparent in Figure 2.

In performing the stepwise variable selection for infestation of the peridomestic structure, *Distance* and *Goats* were selected by Efroymson's method. Results of the logistic regression are presented in Table 3. *Distance* was extremely significant and the *P*-value for *Goats*, after accounting for *Distance*, was more marginal at 0.025. The majority of households with goat pens had infested peridomestic structures, but as seen in Table 2, the correlation between *Goats* and *Distance* was 0.50. Figure 4a displays the spread of fitted values returned by the S-plus *predict* function with *Distance* and *Goats* for uninfested versus infested peridomestic structures. Small random offsets were applied to the X axis of plotted points, so that the sample density was not obscured by overlapping symbols. As shown in Table 4, by back-classifying infestation status based on a fitted probability of less than or greater than 0.5, the percent correctly classified was 87%. The Type I and II error rates show some systematic underprediction of infestation.

When considering just infestation of domiciles, no other variables made a significant contribution beyond the sole use of *Distance*. Results of the logistic regression are presented in Table 5. Figure 4b displays the spread of fitted values for uninfested versus infested domiciles. While the dominant cluster of uninfested samples is distinct from the fitted values of infested samples, there is notable overlap in the tails of the

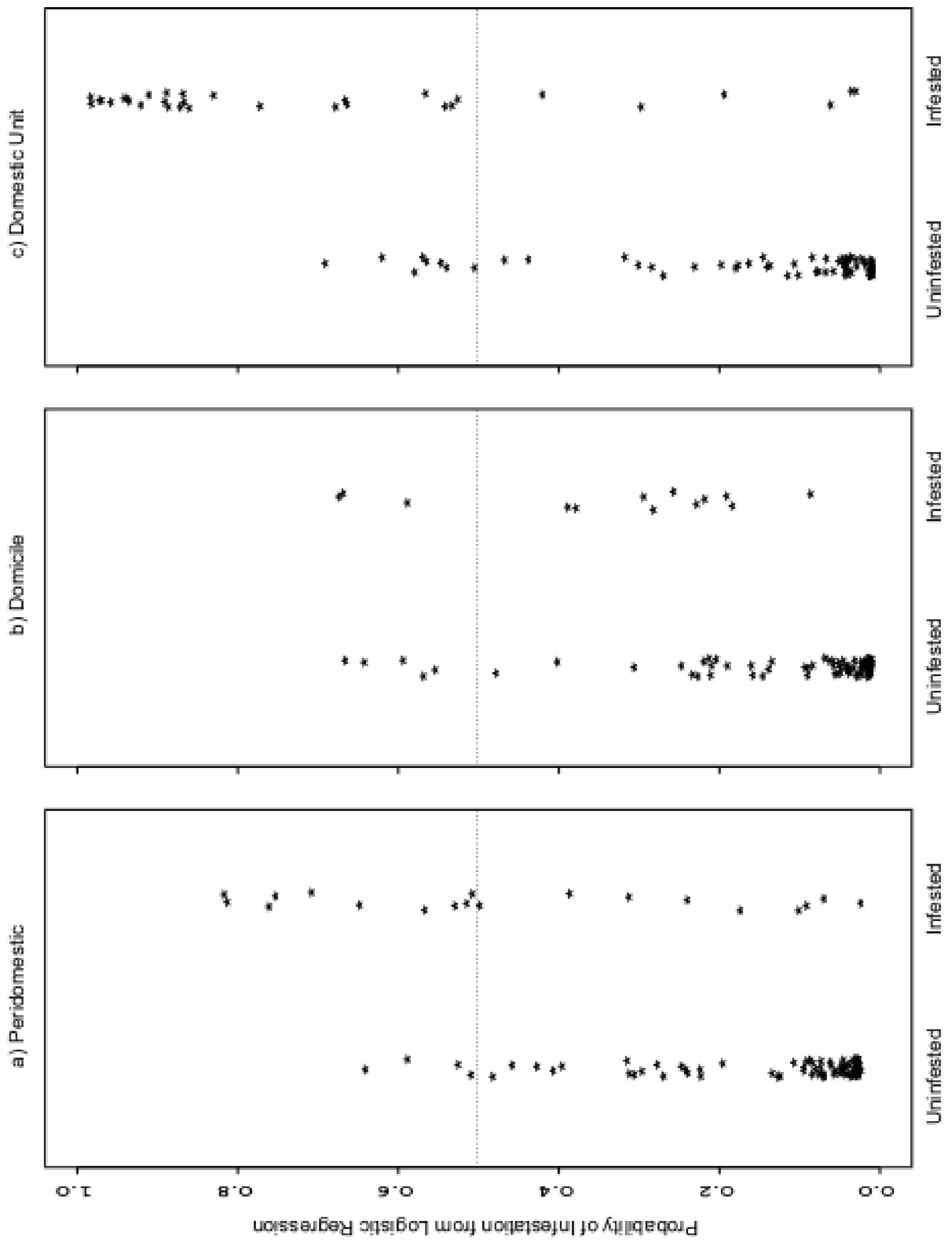

Figure 4. Fitted values versus infestation status: a) peridomestic, b) domicile, c) domestic unit.

Table 2. Cross-correlation of independent variables.

	Roof	Occupants	Kitchen	Dining	Bedrooms	Poultry	Goats	Pigs	Animals	Distance	Neighbor
Occupants	0.24										
Kitchen	-0.27	0.05									
Dining	-0.26	-0.08	0.16								
Bedrooms	-0.09	0.13	0.03	-0.01							
Poultry	-0.08	-0.08	0.04	0.02	0.10						
Goats	0.25	-0.05	-0.26	-0.13	0.01	-0.02					
Pigs	0.16	0.17	0.00	-0.15	0.01	0.06	0.24				
Animals	0.03	-0.10	-0.07	-0.04	0.17	0.72	0.55	0.33			
Distance	0.62	0.19	-0.44	-0.17	-0.02	-0.09	0.50	0.13	0.17		
Neighbor	0.31	0.16	-0.02	0.05	0.13	-0.07	0.27	0.23	0.13	0.31	
Density	-0.55	-0.18	0.26	0.00	-0.01	-0.03	-0.31	-0.11	-0.16	-0.76	-0.37

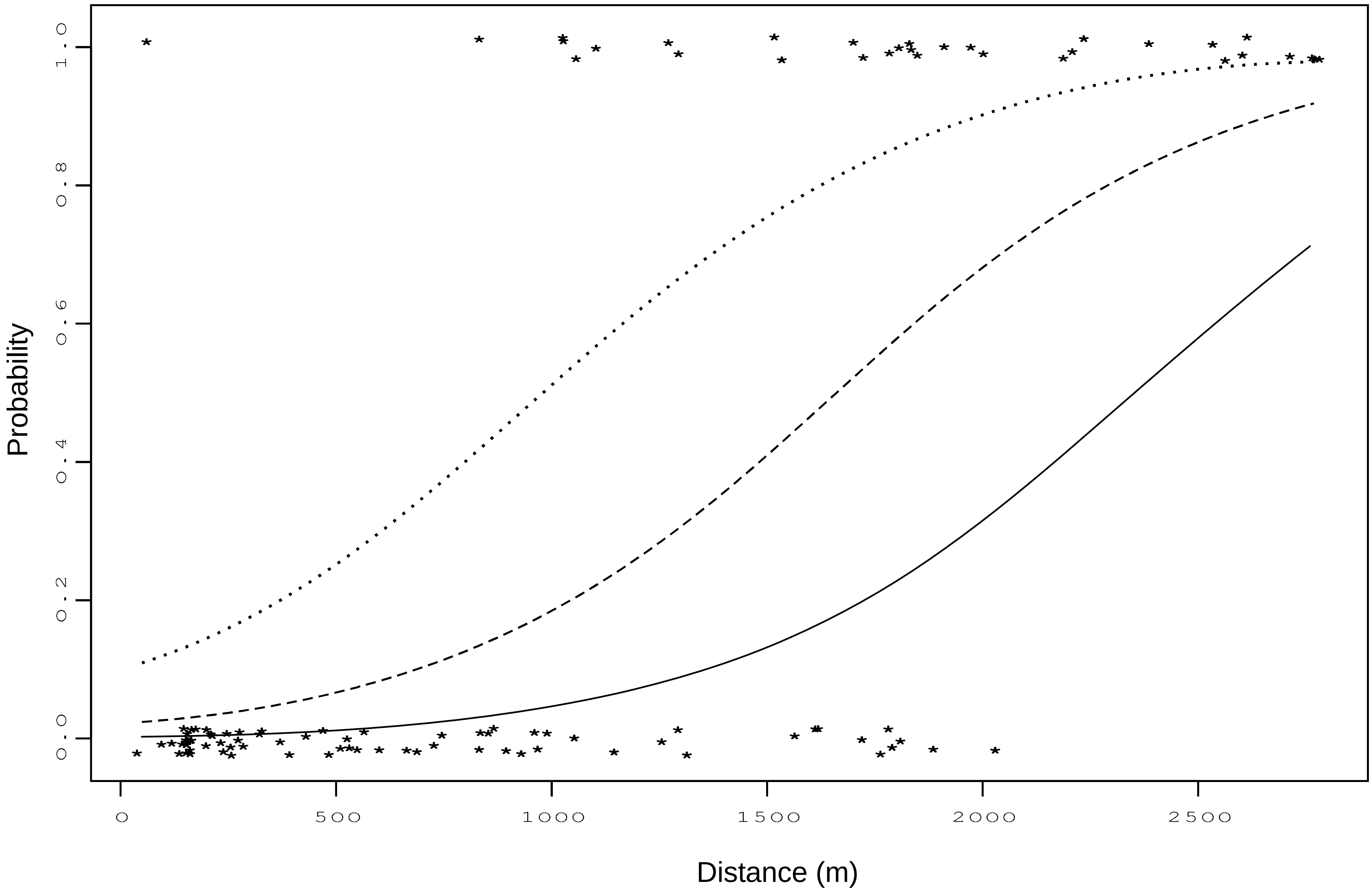

Figure 5. Probability of infestation versus *Distance* for thatched with animal pens (dotted), thatched without pens (dashed), and modern construction without pens (solid).

Table 3. Logistic regression for peridomestic environment.

Variable	Value	Std. Error	*t* value	*P* (F-test)
Intercept	-3.9138	0.7630	-5.1293	-
Distance	0.0015	0.0005	3.4402	< 0.00001
Goat	1.1155	0.6592	1.6923	0.02472

Table 5. Logistic regression for domiciles.

Variable	Value	Std. Error	*t* value	*P* (F-test)
Intercept	-5.0181	1.3399	-4.8532	-
Distance	0.0021	0.0005	3.903	< 0.00001

distributions. As shown in Table 4, the percent correctly classified was 85%. Again, the Type I/II error rates show some systematic underprediction of infestation.

When considering the entire domestic unit, the selected variables were *Distance*, *Animals*, and *Roof*. Results of the logistic regression are presented in Table 6. Again, *Distance* was extremely significant, while the other two had more marginal *P* values. It seems clear that goats played the largest role among subtypes of *Animals*. Though *Roof* had one of the clearest causal links to infestation of domiciles, its significance was marginal. This is primarily due to its strong correlation with *Distance*. Figure 4c displays the spread of fitted values for uninfested versus infested domestic units. The spread of fitted values shows a much better differentiation when considering the entire domestic unit. As shown in Table 4, the percent correctly classified was 86%. The Type I/II error rates show little bias with respect to over or underprediction.

For variables that are characterized by continuous spatial variability, like *Distance* or *Density*, it is possible to map the probability of infestation. In cases where non-spatial variables (e.g. *Roof*, *Goat*) are also included in the logistic regression, those variables may be set to 0 or 1 to create multiple probability surfaces that may be mapped in two dimensions. For example, Figure 5 uses the logistic regression of Table 6 to map the probability of infestation in the domestic unit based on *Distance* for households with thatched roofs and animal pens (dotted), thatched roofs without pens (dashed), or modern construction with no pens (solid). Plotted points in Figure 5 present the actual presence or absence of *T. infestans* from the field survey, with small random offsets applied to the Y axis to avoid overlapping symbols. The logistic regression for domestic units was converted into a map of infestation probability by calculating a surface representing the distance to the centroid of the uninfested zone and applying the logistic regression equation. Figure 6 presents the probability surface for infestation of domestic units with thatched roofs and animal pens for the area corresponding to Figure 2. Symbols superimposed on the map denote the actual infestation status of households and show the strength of the relationship.

Table 4. Classification results (% correct, Type I error, Type II error).

	PCC	Type I	Type II
Peridomestic	87%	0.09	0.04
Domicile	85%	0.10	0.05
Domestic Unit	86%	0.06	0.08

DISCUSSION

It has been observed that after a massive spraying of a rural community with piretrine insecticide, like Chancaní in 1996 (Chuit et al. 1992, Segura et al. 1999), the dwellings usually experience rapid reinfestation (Dias 1963, Pinchin et al. 1980, Gualtieri et al. 1984, Oliveira Filho et al. 1986, Paulone et al. 1988, Chuit et al. 1992, Gürtler et al. 1994) unless entomological surveillance and intervention immediately follow the initial control effort (Segura et al., 1999). In Chancaní, a relatively low intra-domiciliary infestation index (13.5) and colonization index (at least one live *T. infestans*, 5.4) contrasts with the peridomestic infestation and colonization indices (20.7 and 29.7, respectively). These results are similar to those of Cecere et al. (1997) for rural areas of Argentina that attribute reinfestation after a massive spraying with deltametrine (25 mg/m^2) to the presence of protected refuges in the peridomestic environment.

Considering the importance of the *Distance* variable, it is plausible that there were a greater number of refuges for *T. infestans* in the outlying areas that had lower housing density than residences in the town center. However, survival in outlying refuges might not adequately explain the current spatial pattern of infestation. Given that five years had elapsed since the last insecticidal campaign, there would have been ample opportunity for dispersal to susceptible structures in the town center. While single dispersal flights for *T. infestans* are commonly less than 200 m, a measurable fraction travel more than 0.5 km (Schofield et al. 1992). Schweigmann et al. (1988) document single dispersal flights of up to 2 km in a natural setting. The radius of the entire study area was less than 4 km.

Although there were clear reasons for the lower rate of infestation in dwellings constructed with modern materials than with thatched roofs (8% versus 57%, respectively), it is interesting that the spatial configuration of households was more statistically significant. Since modern roofing materials in Chancaní were more common in the town center, *Distance* indirectly captured much of the information associated with roof type. However, results showed that *Distance* provided additional information. It may be that the preponderance of modern roofing in the town center provided a prophylactic effect for nearby thatched households. A lack of suitable thatch habitat in the vicinity might limit the number of insects

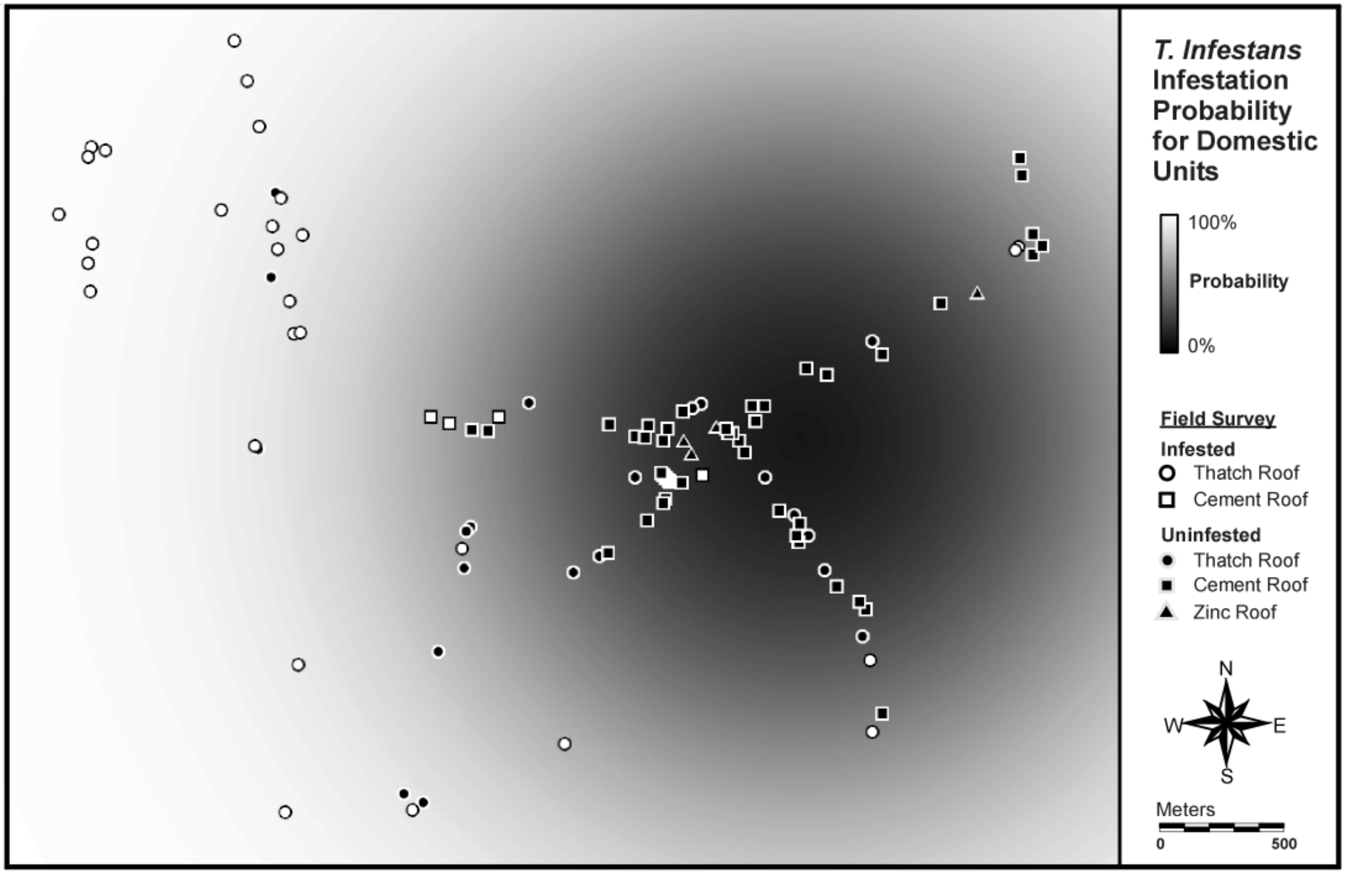

Figure 6. Map of infestation probability for domestic units.

Table 6. Logistic regression for domestic units.

Variable	Value	Std. Error	*t* value	*P* (F-test)
Intercept	-5.2214	1.0062	-5.1792	-
Distance	0.0022	0.0006	3.9468	< 0.00001
Animals	1.4993	0.6733	2.2267	< 0.03566
Roof	1.5310	0.7587	2.0181	< 0.03500

available to disperse into a susceptible household, as well as the potential directions from which they would arrive. Thus, while the potential dispersal distance could easily cover the entire village in a short period of time, actual reestablishment after eradication might be reduced. In addition to correlations between *Distance* and physical aspects of the environment, *Distance* would likely integrate a number of relevant social effects. For example, the local hospital is located in the center of town near the centroid for *Distance*. Proximity to health care personnel may affect the ongoing vigilance of the population to factors that may lead to infestation. It is interesting that *Roof* was only found to be significant by the stepwise selection method when the entire domestic unit was analyzed. Thus, it seems that the method of domiciliary construction reflected more generally on the site as a whole in a way that was discernable from *Distance*.

The second most significant *P*-value of the stepwise analyses was the *Goats* variable for indicating infestation of peridomestic structures. It is notable that all 14 of the thatched houses with goat pens were infested in either the domicile (six cases) or peridomestic structures (11 cases). This association suggests a risk factor that should be examined in more detail.

Modern geospatial technologies, such as global positioning systems (GPS), satellite remote sensing, and geographical information systems (GIS) provide useful methods for better understanding the geographical distribution of infestation. In this study, the incorporation of field survey results into a GIS allowed the accurate calculation of position and housing density. GIS-derived information (*Distance*) provided the single strongest relationship to infestation by *T. infestans*. Remote sensing and GIS methods may be expected to make more sophisticated contributions, through their ability to identify the conjunction of various life-cycle requirements for vectors over space and time (e.g. Srivastava et al. 2005, Boone et al. 1998, Beck et al. 1994).

A comparison between results for Chancaní and other rural settlements is needed to assess the generality of the results. For example, Chancaní could be compared to another rural area where the pattern of housing density or livestock is not so correlated with radial distance from a single town center. While this study was entirely correlative, the strong association between domicile location and infestation status points to the need for further study to determine the physical and social controls on dispersal and establishment of *T. infestans*, such as a possible broader prophylactic effect of cement structures. For example, in the structure-rich environment of a town, does dispersal occur as shorter hops to direct neighbors, where unsuccessful establishment in modern materials may result in reflection back to the source area? In cases where the probability of infestation is found to depend on some aspect of location, maps of infestation probability may provide a tool to assist with local decision-making with respect to ongoing surveillance, allocation of resources for eradication, public land use (e.g. location of schools), and possible preventive land management strategies to combat Chagas disease in the region.

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