Comparison Between Two Artificial Shelter Units and Timed Manual Collections for Detecting Peridomestic *Triatoma infestans* (Hemiptera: Reduviidae) in Rural Northwestern Argentina

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ABSTRACT   A new artificial shelter unit was compared with segments of bamboo cane lined with pleated filter paper for detecting peridomestic *Triatoma infestans* Klug at Amamá and nearby rural villages in northwestern Argentina. The new shelter unit consisted of a black plastic, wide-mouthed jar with a screw cap on the top, and a removable central structure made of pleated corrugated paper. In devices exposed from February to December 1999 at 24 sites positive for *T. infestans* by timed manual collections with an irritant in April 1999, the cumulative percentage of sites with any sign of infestation detected by the shelter unit increased from 71% after 2 mo to 96% after 10 mo, whereas bamboo cane units concurrently detected only 12–42% of the sites. Sensitivity increased with time of exposure and the abundance of *T. infestans* per site. In 19 sites negative for *T. infestans* by inspection, shelters increasingly detected infestation at 16–63% of sites after 10 mo, whereas the bamboo canes only detected one infestation. Shelter units inspected three times over an 11-mo period were significantly more sensitive than a single manual search with an irritant performed in March 2000. Our study provided conclusive field evidence that the shelter unit was more sensitive for detecting peridomestic *T. infestans* than were timed manual searches, the standard reference method, or bamboo cane units. Rapid timed searches by skilled bug collectors during the early surveillance phase overlooked many peridomestic populations that, in the absence of control, inevitably would increase in abundance and repopulate treated areas.

KEY WORDS   *Triatoma infestans*, Chagas disease, Argentina, surveillance, sampling, vector control

THE PERIDOMESTIC ENVIRONMENT is an important source of triatomines of public health importance (Ronderos et al. 1980, Zeledón and Rabinovich 1981, Dias 1991). Peridomestic ecotopes, such as goat, pig, or horse corrals; tool sheds; chicken houses; and outdoor kitchens, are bug habitats with associated hosts situated near bedrooms and other areas of human activity. In northwestern Argentina, the majority of rural houses typically have three to eight such peridomestic ecotopes scattered within a 120-m radius around human sleeping quarters, and these frequently are infested with *Triatoma infestans* Klug and other triatomines (Cecere et al. 1997, Canale et al. 2000). Peridomestic populations of *T. infestans* that survived a single application of residual pyrethroids most likely were the source of bugs that reinfested human habitations in rural northwestern Argentina (Cecere et al. 1997) and Bolivia (Dujardin et al. 1996). The regional elimination of *T. infestans*, as supported by the Southern Cone Initiative (Schmunis et al. 1996), requires a sensitive,

simple, and widely applicable method for detecting infested peridomestic sites that can be used by the affected communities. Such a sensitive tool is also indispensable to stratify control efforts during an eradication attempt, and to study the spatial and temporal dynamics of reinfestation at a community-wide scale with the objective of designing improved control strategies.

Timed manual collections using an irritant spray (the "flushing-out" method) has been the standard method to assess the occurrence and intensity of infestation by triatomine bugs (Schofield 1978, Rabinovich et al. 1995). However, this method is costly, requires skilled staff, and lacks sensitivity and precision. Moreover, little is known about the sampling efficiency of timed manual collections in peridomestic ecotopes, particularly those having complex structure (e.g., goat corrals made of piled thorny branches). In human habitations, timed searches have proved less sensitive and costlier than triatomine sensing devices made totally of cardboard or paper (Chuit et al. 1992, García-Zapata and Marsden 1993, Gürtler et al. 1999), but these materials and the devices' shape are inappropriate for most peridomestic ecotopes.

A previous method for sampling outdoor sites consisted of segments of bamboo lined with pleated paper, but these were not effective for sampling sylvatic

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triatomines in Venezuela (Tonn et al. 1976). In contrast, bamboo cane apparently was effective for detecting *T. infestans* in chicken houses in central Brazil (García-Zapata and Marsden 1993), but not in a wider variety of peridomestic ecotopes in northwestern Argentina (O.D.S. and Roberto Chuit, unpublished data). Therefore, we developed two types of artificial refuges consisting of a black plastic jar with different internal structure (De Marco et al. 1999). These units were resistant to weather conditions and accounted for several features of triatomine behavior (negative phototaxis, thigmotaxis, and preference for dry sites). In a small field trial involving 13 *T. infestans*-positive sites, one of the units was significantly more sensitive than concurrently monitored bamboo cane (De Marco et al. 1999). To assess the sensitivity of these units for detecting *T. infestans* in a larger area with greater variety of peridomestic ecotopes over different seasons, we conducted a 10-mo long trial comparing bamboo cane and the best configuration of the black plastic jar unit at sites determined to be positive and negative for *T. infestans* by timed searches. We then compared the sensitivity of the jar shelter units with timed manual searches using an irritant at the same peridomestic sites.

Materials and Methods

Sensing Devices. The units used in our study were described previously by De Marco et al. (1999). The bamboo device consisted of segments of bamboo cane, *Guadua trinii* (12 cm long and 2.5 cm i.d.) lined with pleated filter paper. The shelter unit was a commercially available black plastic, wide-mouthed jar 19 cm high and 10 cm diameter, with a screw cap at the top, and two openings in the bottom, each measuring 3 cm high and 7 cm wide. The floor was coated with commercially available brown (3 mm thick) bovine leather, with the rough surface facing toward the inside. The internal surface was covered with corrugated paper. All devices and materials had not been used previously and were not treated with any substance.

Study Site. Fieldwork was carried out in Amamá, Trinidad and Mercedes (27° S, 63° W), Province of Santiago del Estero, Argentina. The area is semiarid with a thorn forest. Amamá was sprayed with deltamethrin in 1985 and 1992 (Gürtler et al. 1994, Cecere et al. 1997). *T. infestans* is the only triatomine species colonizing bedrooms, but *Triatoma garciabesi* Carcavallo, Cichero, Martínez, Prosen & Ronderos and *Triatoma guasayana* Wygodzinsky & Avalos typically infest peridomestic and sylvatic areas (Gürtler et al. 1999, Canale et al. 2000). Because of their distribution and very low infection rates with *Trypanosoma cruzi* (Cecere et al. 1999), *T. garciabesi* and *T. guasayana* are not considered targets for control at present.

Study Design. As part of an ongoing surveillance program, in December 1998 two to three skilled bug collectors from the National Chagas Service searched for triatomines in all bedrooms and peridomestic areas of 114 houses using the irritant 0.2% tetramethrin

(Icona, Argentina) to flush out the insects (Gürtler et al. 1995). Searches usually were conducted between 0800 and 1500 hours on non-rainy days. During 30 min per house, one or two men searched bedrooms (1 person-hour), and another man searched peridomestic ecotopes (0.5 person-hour). In April 1999, all peridomestic sites again were searched for triatomines by the same person using 0.5 person-hour per house. All bugs were removed, identified to species, and counted by stage as described by Canale et al. (2000).

All peridomestic sites where *T. infestans* had been captured by timed manual searches in December 1998 and a similar number of negative sites located <500 m distant from the infested sites were used in our study. Houses inhabited irregularly or recently sprayed with insecticides were excluded. In total, 76 pairs of numbered shelter units and bamboo canes were installed in 45 peridomestic sites (one or two pairs per site) at 34 houses between 11 and 19 February 1999. These included 23 infested peridomestic sites from 19 houses (eight goat or sheep corrals, six pig pens, six storerooms or tool sheds, two chicken coops or nests, and one pile of diverse materials). The 22 apparently uninfested sites included three goat or sheep corrals, four pig pens, two storerooms or tool sheds, nine chicken or pigeon coops or duck nests, three mud ovens, and one cart. Both devices were secured using malleable wire and placed vertically at ground level, or on the walls or wooden poles that supported the roof. The exact location sites of the devices took into account the particular features of the infested site and the purported refuge-host pathway of the bugs. A total of 48 houses and their adjoining peridomestic structures, and six peridomestic study sites, were sprayed with deltamethrin (K-Othrina, Agrevo (Buenos Aires, Argentina), 2.5% suspension concentrate at 25 mg (AI)/m²) by community leaders or house owners between December 1998 and March 2000.

To enlarge the study base, in April or September 1999, 25 additional pairs of sensing devices were installed in 24 peridomestic sites (six storerooms or tool sheds, eight pig pens, six goat corrals, three chicken coops, and one fence). Five of these sites were positive for *T. infestans* by timed manual collection; nine sites had been positive in 1997–1998, and 10 sites had been negative throughout. Both devices were removed from two sites in April and two sites in September because of the absence of hosts, or the destruction of the habitat. In September 1999, because of frequent damage or loss of devices located on the ground of goat or sheep corrals or pig pens, devices in 18 sites were relocated horizontally beneath the thatched roof. The entrances were relocated accordingly by making longitudinal cuts (5 cm long by 2 cm wide) in the walls of each shelter unit. Unless damaged, the same devices were used in all the 69 study sites from February to December 1999.

A first inspection of the sensing devices for early evidence of infestation was carried out in each of 10 houses with a *T. infestans*-positive peridomestic site 4–6 d after initial exposure. All devices were inspected between 11 and 14 April 1999, 1 and 9 September 1999,

and 10 and 16 December 1999. To minimize the loss of eggs or other signs, the devices were handled in a deep plastic tray. The number of bugs, exuviae, eggs, and triatomine dejecta in the interior and exterior of each device were counted and recorded. Bugs, exuviae, and eggs were removed, whereas triatomine dejecta were marked to avoid their inclusion on the following round. Triatomine dejecta were tested with phenolphthalin (see below). When triatomines or other signs of infestation were detected in any device, the central structure, inner coating, and the pleated paper were withdrawn and replaced.

In the second phase of our study, we compared the sensitivity of shelter units with timed manual collections using an irritant. New shelter units were installed at the same study sites in December 1999 and inspected for evidence of infestation in March 2000, concurrent with timed collections.

For timed manual collections, the terms "infested" or "positive" meant finding at least one live or moribund *T. infestans.* For the sensing devices, these terms meant that at least one sign of infestation (i.e., *T. infestans* bugs, eggs or exuviae, or triatomine fecal smears) were detected. However, given the occurrence of other species of triatomines that might leave dejecta indistinguishable from those of *T. infestans,* we considered separately infestations based on the finding of triatomine dejecta alone and those with other specific *T. infestans* signs. For our purposes, the finding of *T. garciabesi* or *T. guasayana* bugs, exuviae, or eggs in a sensing device was disregarded as evidence of infestation.

Laboratory Methods. The phenolphthalin (Kastle–Meyer) test was used to confirm if black or dark brown dejecta attributed to triatomines on morphological grounds (form, size, and color) contained heme, which are absent from other domestic or peridomestic arthropods' feces (Gürtler et al. 2001). In April 1999 the central cardboard structure with triatomine-like dejecta was replaced and transported to Buenos Aires for further testing, whereas in September and December 1999 on-site tests were carried out. In April and September, all triatomine-like black or dark brown dejecta were tested, but because their number was large in December, we tested a maximum of 10 dejecta per device to verify that al least one was phenolphthalin-positive.

Data Analysis. Because several sites positive for *T. infestans* by timed collections in December 1998 apparently were negative thereafter, sites positive in April 1999 were the sampling units used to estimate the sensitivity of shelter units and bamboo canes from February to December 1999. We assumed that each device at a given site performed independently of other devices in different sites within the same house. When there were two pairs of devices per site, the results for each type were combined by site. Sites in which the devices had missing data for >50% of the study period were excluded from longitudinal analyses. Given the matched study design, each pair of shelter units and bamboo cane was taken as the sampling unit to test their relative effectiveness; pairs with
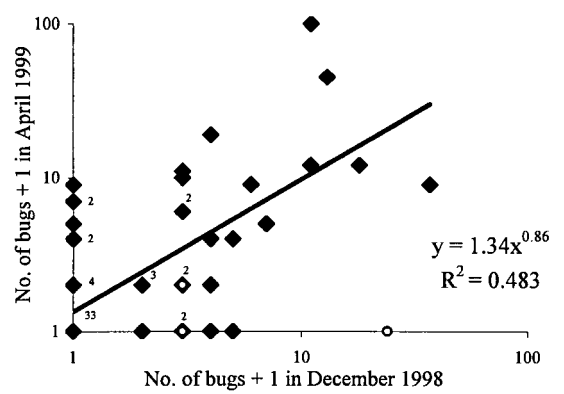

Fig. 1. *Triatoma infestans* bugs collected by timed manual searches with an irritant in 69 peridomestic sites, Amamá and nearby villages, December 1998 and April 1999. Numbers beside triangles represent repeated data points. Empty triangles represent sites sprayed with insecticides between surveys.

one or two missing devices were excluded from analysis. The significance of the differences observed between devices was tested by the one-tailed binomial test, assuming equal probability of detection for each method (Zar 1996). In the absence of a previous paired trial of shelter units and timed searches, we carried out two-tailed binomial tests.

Results

Triatoma infestans bugs were collected by timed manual searches in human sleeping quarters of one house (two bugs) and in 29 peridomestic sites of 23 houses (165 bugs) in December 1998, in 30 peridomestic sites at 23 houses (193 bugs) in April 1999, and in human sleeping quarters of 15 houses (62 bugs) and in 41 peridomestic sites of 29 houses (266 bugs) in March 2000. The log-transformed abundance of *T. infestans* per peridomestic site in December and April was significantly correlated ($r = 0.695$, $P < 0.001$; $n = 66$, excluding three sites sprayed with insecticides; Fig. 1). Most of the infestations were very low-density (median in April, four bugs per site). Persistent peridomestic colonies of *T. infestans* were detected in 20 study sites inspected in December and April. Four (17%) of the unsprayed sites positive in December were negative in April, whereas 10 (23%) of the sites negative in December were positive in April. *T. garciabesi* or *T. guasayana* co-occurred with *T. infestans* in double or triple associations at 10 study sites; *T. garciabesi* alone was collected at two sites negative for *T. infestans* in both inspections.

Of 76 and 97 pairs of devices installed in February and April 1999, respectively, 87 and 84% of the shelter units and 78 and 63% of the bamboo canes were recovered in the following survey. Of 95 pairs installed in September 1999, the recovery rate increased to 96% of the shelter units and 75% of the bamboo cane in December 1999, probably because they were moved from the ground to the roof of goat or sheep corrals
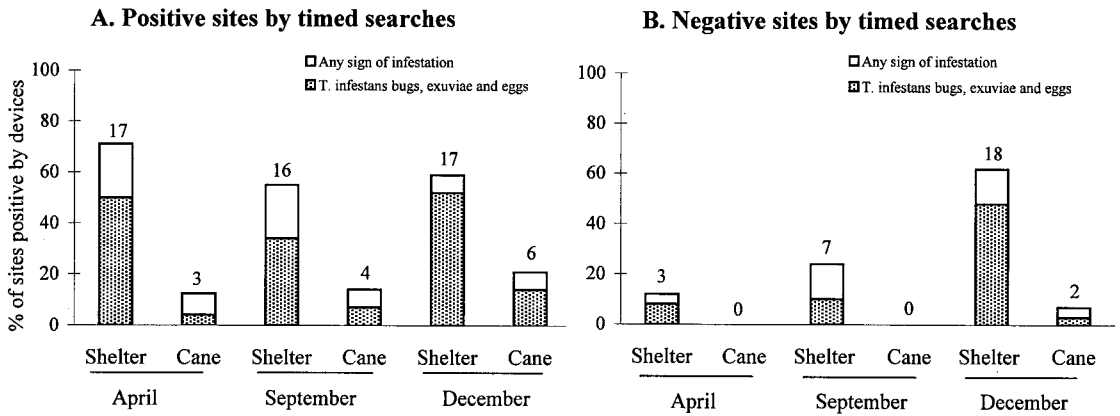
Fig. 2. Infestations by *T. infestans* detected using one to two matched pairs of shelter units and bamboo cane in peridomestic sites that were positive (A) or negative (B) by timed manual collections in April 1999, Amamá and nearby villages, February–December 1999. Empty bars are based on the finding of any sign of infestation, excluding *T. garciabesi* or *T. guasayana;* hatched bars are based on *T. infestans* bugs, exuviae, or eggs. Numbers on top of each bar represent the total number of positive devices per survey date.

and pig pens. The shelter units were recovered more frequently than the bamboo canes in all surveys, although statistically significant differences were found only in September ($\chi^2 = 10.5$, $P = 0.001$) and December ($\chi^2 = 16.7$, $P < 0.0001$).

Four to six days after initial exposure, the shelter units recorded a total of 22 adult and nymphal *T. infestans* and one *T. garciabesi* nymph in four (40%) of the positive sites examined, whereas all the bamboo canes were negative. Fig. 2 shows the percentage of sites positive by sensing devices on three inspection dates based on finding of *T. infestans* bugs by timed manual collection in April 1999. As new study sites were included in April and September, all sites and devices were not exposed for the same amount of time. At positive sites, the percentage with any sign of infestation detected by the shelter units varied from 71% in April ($n = 24$) to 55% in September ($n = 29$) and 59% in December ($n = 29$). The paired bamboo canes detected only 12–21% of the positive sites. At negative sites, the percentage of shelter units that detected infestation increased from 12% in April to 62% in December 1999, whereas the bamboo canes rarely detected any infestation. The shelter unit detected a similar number of infestations (56 of 78, 72%) through specific signs of *T. infestans* (bugs, eggs, or exuviae) as did the bamboo cane (8 of 15, 53%) ($\chi^2 = 2.0$, $P = 0.157$).

Detection of peridomestic infestations increased as a function of time after exposure of the sensing devices and with the abundance of *T. infestans* per site as assessed by timed manual collections in April 1999 (Fig. 3). In 24 *T. infestans*-positive sites monitored from February to December, the cumulative percentage of sites with any sign of infestation detected by the shelter unit increased from 71% after a 2-mo exposure to 96% at 10 mo, whereas the paired bamboo canes only increased from 12 to 42% of the sites. The single undetected positive showed no evidence of infesta-

tion by any method through March 2000. In 19 *T. infestans*-negative sites, the shelter units increasingly detected infestation from 16 to 63% after 10 mo, whereas the bamboo canes only detected one infestation (Fig. 3B). In another group of devices installed in April or September and followed through until December, shelter units detected three of five *T. infestans*-positive sites, whereas the bamboo canes were all negative (not shown). Of 19 negative sites in April, shelter units detected specific signs of *T. infestans* and triatomine dejecta in nine (47%) sites, whereas bamboo cane only detected one (5%) positive site. Most infestations detected by the shelter units or bamboo canes in negative sites probably were newly established, because nearly all of them also had been negative by timed manual collection in December 1998.

When each complete pair of sensing devices was taken as the sampling unit, the shelter units were significantly more sensitive than the matched bamboo canes for detecting *T. infestans*-positive sites in the three surveys, and in negative sites in two surveys (Table 1). The bamboo cane never detected infestations that were missed by the shelter units. Some numbers in Table 1 differ from those in Fig. 2, because the table only includes complete pairs of devices, not sites.

The shelter units collected a much greater number of *T. infestans* bugs and other signs than the bamboo cane (Table 2). Bugs, exuviae, and eggs decreased from April to September, after the cold season, and increased sharply in December. Triatomine dejecta in the shelter units increased from April to December. The percentage of triatomine-like dejecta that tested phenolphthalin-positive was 82% (36 of 44) in April, 75% (125 of 167) in September, and 95% (389 of 409) in December 1999. The log-transformed ratios of the total number of bugs or signs in each shelter unit to those on the matched bamboo cane from February to December was taken as a measure of their relative sampling efficiency. The mean log ratio was 0.62 (SE =
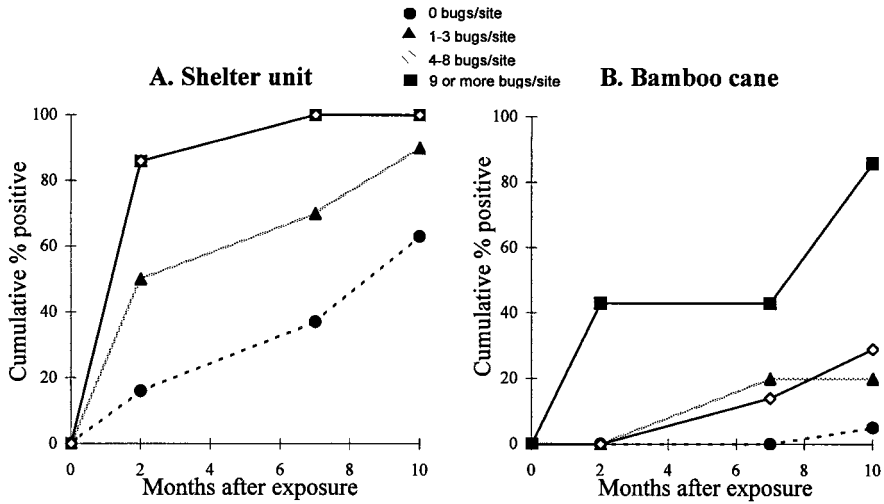
Fig. 3. Sensitivity (expressed as a cumulative percentage of positive sites) of shelter units (A) and bamboo cane (B) according to months after exposure and the number of *T. infestans* bugs collected per site by timed manual searches in April 1999, Amamá and nearby villages, February–December 1999. Numbers of study sites were 19, 10, 7, and 7 for timed collections of 0, 1–3, 4–8, and ≥9 bugs per site, respectively.

0.068); the antilog is the geometric mean ratio, 4.2 (95% confidence interval, 1.87–6.45). Therefore, on average, each shelter unit recorded 4.2 times more signs or bugs than the matched bamboo cane.

Triatoma garciabesi bugs and exuviae were collected from three to four shelter units in each survey, and *T. guasayana* only once (Table 2). *T. infestans* co-occurred with *T. garciabesi* in 3 units, and with *T. guasayana* only once. From February to December, *T. garciabesi* or *T. guasayana* bugs were collected within the shelter units only in one of five sites where they had been caught by timed searches in April, and from five of 41 sites negative for these species. Other animals were found within the shelter units, including small lizards (*Gecko* sp., known to predate on triatomine bugs), spiders of various sizes, crickets (predators of triatomine eggs), and more rarely, cockroaches (whose dejecta might be confounded with those of triatomine bugs). A dead adult *T. infestans* with partly chewed head and legs was found in 1 unit.

Shelter units exposed since February and timed manual collections with an irritant did not differ sig-nificantly in their sensitivity to detect any evidence of triatomine infestation by April 1999, but timed searches were significantly more sensitive than the bamboo canes (Table 3). Shelter units inspected three times over 11 mo from April to March 2000 were significantly more sensitive than timed manual collections performed in March 2000, either when infestations assessed by the shelter units were based on any evidence of triatomine infestation ($P < 0.002$) or specific signs of *T. infestans* ($P < 0.02$). A total of 32 (42%) shelter units yielded 137 *T. infestans* bugs, 102 exuviae, 369 eggs, and 797 triatomine dejecta.

A preliminary cost estimate for each shelter unit was $1.74, based on retailer prices at Buenos Aires, and included $1.07 for materials (plastic jar, leather, corrugated paper, and wire) and $0.67 for 8 min of labor (cutting and assemblage, assuming $5 per labor hour). The cost of bamboo cane was $0.20 per unit. Additional expenses related to field work totaled $1.41, including a search for a suitable site and deployment of devices, $0.58 or 7 min; and inspection and reinstallation of devices, $0.83 or 10 min.

Table 1. Detection of peridomestic infestations by *T. infestans* using one to two matched pairs of shelter units and bamboo canes at sites that were or were not found infested by timed manual collection in April 1999, Amamá and nearby villages, February–December 1999 (numbers in the table are for complete pairs of devices)

Inspection date	Infestation by timed searches	Positive[a] only by shelter	Positive only by bamboo	Positive by both devices	Negative by both devices	One-tailed binomial test
April	Positive	16	0	5	13	$P < 0.001$
	Negative	3	0	0	21	$P > 0.1$
September	Positive	14	0	4	14	$P < 0.001$
	Negative	7	0	0	21	$P = 0.008$
December	Positive	15	0	8	14	$P < 0.001$
	Negative	16	0	2	16	$P < 0.001$

[a] Positive here means any sign of infestation: *T. infestans* bugs, exuviae or eggs or triatomine fecal smears.

Table 2. Number of triatomine bugs and signs of infestation recovered from the matched peridomestic devices in three inspection dates, Amamá and nearby villages, February–December 1999

| Inspection date | Device | No. (%) of positive[a] devices | No. of T. infestans | | | No. of triatomine dejecta | No. of | |
			Bugs	Exuviae	Eggs		T. garciabesi	T. guasayana
April	Shelter	24 (36)	74	36	69	92	13[b]	1[c]
	Bamboo	5 (8)	1	0	0	15	0	0
September	Shelter	32 (40)	66	8	38	262	7	0
	Bamboo	4 (7)	1	1	0	2	0	0
December	Shelter	49 (54)	476	289	826	818	35[b]	0
	Bamboo	10 (14)	63	27	2	67	0	0
Total	Shelter		616	333	933	1,172	55	0
	Bamboo		65	28	2	84	0	0

[a] Positive means T. infestans bugs, exuviae or eggs, or triatomine fecal smears.
[b] One and two exuviae in April and December, respectively.
[c] Eighteen eggs.

Discussion

Our study provided conclusive evidence that the new jar shelter unit was more sensitive for detecting *T. infestans* populations than timed manual collections with an irritant or bamboo canes in a wide variety of ecotopes differing in construction features and resident hosts, thereby confirming and extending our preliminary study (De Marco et al. 1999). Moreover, the shelter units detected nearly all low-density infestations and new foci missed by bamboo canes, which were effective only at the highest bug densities. We believe that this is the first longitudinal, comparative study of two simple methods for detecting peridomestic triatomine infestations that deals with the very low-density populations that occur after insecticide applications, and shows the low sensitivity of timed manual collections with irritant in peridomestic sites.

Only the shelter units provided suitable conditions that apparently increased the bugs' residence time in its interior and the likelihood of leaving some sign of infestation. The large number of triatomine bugs, exuviae, eggs, and dejecta within the shelter units was evidence of their acceptability as a resting, molting, and oviposition site for *T. infestans.* The bamboo cane (or "cylindrical device") model used by García-Zapata and Marsden (1993) under the roof of chicken coops was larger (50 cm long and 10 cm i.d.) than ours and had one or both ends open, but neither the number and type of signs of infestation in them nor paired comparisons with timed manual searches by site were reported. García-Zapata and Marsden (1993) did not

mention which triatomine species was collected by timed searches or bamboo canes in an area where species other than *T. infestans* invaded houses and colonized peridomestic sites. Interestingly, our shelter units collected a much greater number of bugs, exuviae, and eggs per device than cardboard-made sensing devices ('María' or biosensor boxes) installed in bedroom areas at Amamá for 1 mo (Gürtler et al. 1995), when these areas sustained infestations of greater density than peridomestic sites in 1999–2000. This may indicate either that the shelter units provided a better refuge than cardboard boxes, or that a relative shortage of suitable refuges in peridomestic ecotopes increased the bugs' residence period within the shelter units, or both.

The study sites occasionally were infested by *T. garciabesi* or *T. guasayana*, whose dejecta are indistinguishable from those of *T. infestans* and hence may have led to a false-positive diagnosis of infestation if no other signs were present. Such an error was unlikely in sites positive for *T. infestans* by timed manual collections, because the co-occurrence of *T. garciabesi* or *T. guasayana* within shelter units was rare. An unspecific diagnosis was more likely in negative sites; however, most newly detected infestations revealed specific signs of *T. infestans.* In study sites selected for the occurrence of *T. infestans*, the sensing devices rarely detected *T. garciabesi* or *T. guasayana*.

Our study benefited from extensive data on the location of peridomestic sites infested by *T. infestans* (Cecere et al. 1997, Cecere 1999). Basic information

Table 3. Detection of peridomestic infestations by *T. infestans* using one to two matched pairs of shelter units and bamboo canes, and timed manual collections with an irritant conducted in April 1999 and March 2000, Amamá and nearby villages (numbers in the table are for peridomestic sites)

Inspection date	Device	Positive[a] only by device	Positive only by timed collections	Positive by both methods	Negative by both methods	Two-tailed binomial test
April 1999	Shelter	3	5	17	15	$P > 0.7$
	Cane	0	16	3	17	$P < 0.001$
March 2000[b]	Shelter	19[c]	3	20	14	$P < 0.002$

[a] Positive here means any sign of infestation: T. infestans bugs, exuviae or eggs, or triatomine fecal smears.
[b] Excludes sites sprayed with insecticides in the intervening period, without resident animal hosts or with insufficient exposure of devices.
[c] Six of the foci only detected by triatomine feces.

on the preferred sites of each target species of triatomine is crucial for effective surveillance and early detection. The selection of sites for installing the devices also needs attention because of loss, damage, or disturbance by resident domestic animals. Changing locations from the ground to beneath the thatched roof mainly in goat or pig corrals required adjusting the location of the shelters' entrance, but augmented the recovery rate without apparently diminishing sensitivity. However, the gradual increase in bug abundance or activity after the cold and dry season (April–September) may have overshadowed the effects of changing locations. The occurrence of heavy rainfall apparently did not negatively affect the properties of the materials used in the units or the chance of detecting signs of infestation during September–December, when peak numbers of bugs, eggs, and other signs were observed. If undisturbed by animals, the plastic jar and leather components could be used for at least 2–3 yr, but the less expensive central cardboard structure should be replaced perhaps every 6 mo.

In the absence of insecticidal spraying of the peridomestic study sites during the trial, the abundance of *T. infestans* per site as determined by timed collections was approximately stable from December to April 1999. Moreover, 17% of the unsprayed sites initially found to be *T. infestans*-positive by timed searches in December 1998 were negative by all methods through March 2000. In view of the high sensitivity of the shelter units over an extended period, it is highly likely that those infestations became extinct after removal of bugs. Conversely, many sites negative in December 1998–April 1999 became positive by the shelter units. Although these results are only a subset of the database, they document significant rates of local extinction and colonization of peridomestic sites by *T. infestans* in a short time period.

A single timed manual collection with an irritant was much less sensitive than the shelter unit inspected three times over 11 mo, as observed with cardboard-made triatomine sensing devices used in bedroom areas (Chuit et al. 1992, García-Zapata and Marsden 1993, Gürtler et al. 1999). The longer the exposure period, the greater the likelihood that even a very low-density infestation was detected by the shelter units. Clearly, rapid timed searches by skilled bug collectors during the early surveillance phase may overlook many peridomestic populations of *T. infestans* that, in the absence of treatment, inevitably increase and reinfest the treated areas. This result has significant implications for the *T. infestans* eradication program in rural northern Argentina and the Chaco region.

Many factors affect the performance of timed searches and jointly may explain its low sensitivity when bug abundance is very low. Differences among peridomestic ecotopes in physical structure and accessibility to bugs likely modify the probability of manual capture per unit of effort, and limit comparisons among ecotopes. The searching area is also relevant, but so far it has not been corrected for indices of abundance expressed as number of bugs per person-

hour. In addition, we have observed that low ambient temperatures during manual collections apparently increased the time taken for the bugs to emerge from their natural refuges in reaction to the irritant tetramethrin. For a fixed searching time, low temperatures also would decrease the total catch and therefore sensitivity. The total bug catch increases with time spent searching and the experience of bug collectors (Schofield 1978). In our study, variations in bug capture efficiency among surveys were minimized, because all searches were made by the same 20-yr experienced collector, who surveyed all peridomestic sites every 6 mo over 7 yr. Therefore, the present assessments of peridomestic infestation using timed searches with an irritant are the best that could be hoped for relative to the amount of catching effort expended. On a large regional scale, triatomine surveillance using rapid searches with an irritant may be even less sensitive than in the current study.

The annual cost of triatomine surveillance through timed searches with an irritant was estimated to be $17 per rural house in Argentina (Chuit et al. 1992) and $3.70 in Brazil (García-Zapata and Marsden 1993) in the early 1990s, which exceeds the cost of surveillance using our shelter units or other related devices. Even in its current design, open to improvement and cost reduction, the shelter unit appears to be a sensitive, cost-effective, and widely applicable method for early and continuous detection of *T. infestans* in peridomestic sites, especially during an eradication attempt. It is simple and can be used by the affected communities after minimal training. These shelter units also constitute a valid sampling method to investigate factors associated with local colonization, persistence and extinction of peridomestic *T. infestans* colonies.

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