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Evaluation on the effectiveness of actions for controlling infestation by rodents in Campo Limpo region, São Paulo Municipality, Brazil

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Rodents are responsible for the transmission of more than 60 diseases both to human beings and to domestic animals. The increase in rodent infestation in a given area brings several health problems to the nearby population. Thus, when infestation increases, it is time to take intervention measures. Although many countries have implemented programs aimed at controlling rodent infestation, literature on studies evaluating the effectiveness of intervention measures in urban areas is scarce. Aimed at contributing to the understanding of rodents' population dynamics in urban areas, the objective of this study was to evaluate the effectiveness of the control methods proposed by ''Programa de Vigilância e Controle de Roedores do Município de São Paulo'' (Program for Rodents Surveillance and Control in São Paulo Municipality), conducted on Jardim Comercial District. As a first step, a survey to assess infestation rates was conducted in 1529 dwellings located in the area studied. After that, a chemical control upon rodents was accomplished in every dwelling infested. One week and six months after completion of control measures, a new evaluation on infestation rates was carried out, in order to verify the effectiveness of the procedures taken and to estimate the re-infestation capacity. Initial infestation rate was 40.0%, and the final infestation rate, 14.4%. Therefore, the effectiveness of the control methods utilized was 63.8%. It can thus be concluded that the control methods applied were quite effective.

Keywords: urban rodents; rodent control; rodenticides; rodent infestation; urban rat

Introduction

There are around 2,000 rodent species in the world, which represents approximately 40% of all existing mammal species (Brazil 2002). Although many people consider rodents in general a pest, only a small number of species cause economic damage and transmit diseases to the human being and to domestic animals (Alves 1990). In São Paulo municipality, only three species are considered synanthropic pests: Norway rat (*Rattus norvegicus*), house mouse (*Mus musculus*) and roof rat (*Rattus rattus*) (Garcia 1998).

Rodents are directly involved in the transmission of more than 60 diseases both to human beings and to domestic animals (Alves 1990); among these, the most serious ones

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are the bubonic plague, hantavirosis, leptospirosis, murine typhus, and salmonellosis (Brooks 1973; World Health Organization [WHO] 1992). In the São Paulo municipality, the most serious threat to human health is leptospirosis, which is transmitted through contact with flood water or direct contact with rodents. Only in 2005, 264 cases of leptospirosis were registered in the city of São Paulo, being the Incidence Coefficient 11.36/100,000 cases/inhabitant; among these cases, 30 were fatal casualties; consequently, lethality rate was 11.36%. In the same year, in Campo Limpo, the district where the study was conducted, 24 confirmed cases of leptospirosis were registered (Incidence Coefficient 4.38/100,000 inhabitants), out of which two resulted in death (lethality rate: 8.33%) (COVISA 2006).

Besides the risk of leptospirosis, rodent infestation in urban areas may involve several other threats, such as bites, allergies and salmonellosis. On a study conducted in five New York City boroughs, Childs et al. (1998) found a positive correlation between rodent infestation rates in dwellings and incidence of bites among inhabitants. Perry et al. (2003) found that 33% of inner-city homes had detectable rat allergen, and that the presence of such an allergen was associated with reported rat and mouse infestation in dwellings. The authors concluded that rat allergen sensitization and exposure to such an allergen are associated with increased asthma morbidity in children living in inner-city homes. Hilton et al. (2002) detected the presence of *Salmonella* sp. in 8% of faecal samples of *Rattus norvegicus*, and found that *Salmonella* sp. could be recovered by direct culture up to 86 days, being its viability in faeces sufficient to pose a potential risk of contamination even after rodent infestation control.

Since the presence of rodents in a given area represents a concern to public health authorities when their population undergoes a significant increase, thus jeopardizing the population health and involving economic damage, chemical control measures must be taken, as these measures constitute the quickest and most effective way to eliminate a massive number of animals (Brazil 1990). After implementing this kind of control, a continuous monitoring of rodent population must be also carried out, in view of the well known "boomerang effect", that is, quick re-infestation (Brazil 2002). It is extremely important to know the effectiveness of the control measures adopted, degree of infestation, and also to identify the infesting species so as to ensure that measures aiming at reducing their population are correctly implemented. It is also crucial to determine the degree of effectiveness of the chemical control measures taken, as this will allow calculating the speed according to which the infestation is resumed based on the ratio of survivors, providing also grounds for planning further steps for the control program to be implemented.

Nevertheless, most studies addressing the effectiveness of methods for controlling rodent infestation are limited to crop fields (Mutze 1989; Kay et al. 1994; Villafaña et al. 1999; Ramsey and Wilson 2000; Endepols et al. 2003; Brown and Tuan 2005; Singleton et al. 2005); only a few studies evaluate the effectiveness of measures to control rodent infestation in urban areas (Silva et al. 1992; Villafaña et al. 1995, 1999, 2000); scarce data are available concerning re-infestation rates by synanthropic rodents (Villafaña et al. 1992).

Finally, in view of lack of knowledge on actions to control rodent infestation in urban areas, it is extremely important to evaluate the effectiveness of the methods to control rodent infestation proposed by the "Program for Rodents Surveillance and Control" in São Paulo municipality urban area, as this will allow elucidating the most critical aspects of actions carried out in urban centres and suggest new initiatives to be implemented in the city of São Paulo and in other urban areas.

Methods

Characterization of the area studied

The area studied, Jardim Comercial District (46.78°S and 23.67°W), is located in the Southern region of São Paulo municipality. It is a residential neighbourhood with 9,057 inhabitants. Most residents are low-class people; the average income of the person responsible for the dwelling is around R$500.00/month (equivalent to approximately US$ 280); the average income in São Paulo municipality is approximately R$ 1,200/month (equivalent to approximately US$ 662). A large part of the population is aged between 25 and 30 (IBGE 2000). The region's HDI is 0.72; LI (longevity index) is 0.85; EI (educational index) is 0.78; and II (income index) is 0.53 (Pedroso 2003).

The streets in the area studied are all paved. The total number of dwellings amounts to 2,175, most of them masonry-built but with poor finishing; almost all constructions were built without complying with Brazilian civil construction norms. Treated water reaches 99.7% of the domiciles; sewage collection and disposal system serves 69.6% of the dwellings, and regular collection of solid residues is accomplished in 99.2% of the domiciles existing in the area (IBGE 2000). The area relies on the following public facilities: One Basic Health Unit and five public schools; there is also a private school in the area.

Although in recent years the area has not shown a high incidence of leptospirosis, and only one confirmed case resulting in death was registered in 2004, this area was chosen for study in view of a work previously developed there by the Municipality Environment Committee in the period ranging from August to November 2005; we thought this previous work would facilitate implementation of measures to control rodent infestation, which is the responsibility of public authorities.

Environmental diagnosis and survey on initial rodent infestation

In the first stage, a comprehensive survey covering all dwellings existing in the area under study was conducted, in order to evaluate "Initial Infestation Rates". To do so, the area was fragmented in accordance with the division established by census tracts; the survey encompassed 47 blocks and included 2,175 dwellings, which were visited during the month of August 2005 by Zoonosis Control Agents (five teams, each comprising three agents). For statistical analyzes, though, only 1,529 dwellings whose owners gave permission for a complete inspection were visited. The remaining 646 dwellings were eliminated from the study because they were either closed or their owners did not give permission for inspection.

The environmental variables assessed comprised the following groups: Food sources = animal food, accessible garbage, human food available, and fructiferous trees; harborage sources = waste material/rubbish, construction material, discarded objects, ceiling and wall cracks, and dense bush; access sources = poor building structure and poor sewage system; and rodent infestation, including characterization of infesting species (*Rattus rattus*, *Rattus norvegicus* and *Mus musculus*). In order to check whether the dwellings were infested by rodents, signs indicating the presence of these animals, such as faeces, rub marks, burrows, gnawing, rat runs and trails were investigated both in the internal and external areas of all 1,529 dwellings. All variables were recorded by simply using the word "present" or "absent" as the case might be, and were transformed into binary values 1 or 0, respectively. This stage was conducted according to the method proposed by the Center for Disease Control and Prevention (CDC) (Davis et al. 1977), and data collected were registered in a modified version of a rat survey data sheet (block record) from "Urban Rat Surveys".

Rodent control actions

The second stage of the effort was accomplished during the months of September and October 2005, and consisted in chemical rodent control with an anticoagulant rodenticide plus inspection of all dwellings and places which had shown signs of infestation in the Initial Survey on Rodent Infestation.

For chemical rodent control only hydroxicumarine-based rodenticides having an anticoagulant effect and duly registered at the Brazilian Ministry of Health were utilized. The formulations used were: Paraffin block (brodifacoum 0.005%), pellet baits (bromadiolone and/or brodifacoum 0.005%), and contact dust (cumatetralil 0.75%); the first two formulations are second generation rodenticides, that is, a single-dose chemical product; the contact dust is a first generation rodenticide, that is, a multi-dose chemical product.

Paraffin blocks were used mainly in humid places, such as sewers and look boxes, and, whenever necessary, on roof wood structures (when these were fixed with wire). Pellet baits were placed mainly in the interior of dwellings and roofs, the so-called bait points. Contact dust was applied in burrows and, whenever possible, in rodent trails, with the use of a powderer device or an applicator vial.

The complete chemical rodent control process comprised three treatment phases (three pulsed baiting) with an interval of at least 10 and at most 15 days between each treatment phase. By the time the chemical treatment was carried out, the residents were informed by zoonosis control agents on the rodenticide application and on preventive measures that should be taken to avoid rodents.

In addition to chemical rodent control, other initiatives complementing the integrated management of pests were also implemented: (i) Actions aiming at improving the environment, which included cleaning and desilting the watercourse that runs in the area; eliminating trash – collecting rubbish and discarded materials; cleaning and unclogging burrows; (ii) development of educational actions, such as the project "Rato Fora" (Away with Rats); this action consisted of an advertising campaign through TV and radio providing orientation on measures that help prevent infestation by rodents; and (iii) a campaign to make children and adults aware of the problem; this campaign was promoted by the five public schools located in the district jointly with Jardim Comercial Basic Health Unit. The contribution given by these initiatives for reducing infestation was not directly measured on the occasion they were carried out, but was measured later on by a survey conducted one week after adoption of control methods (Survey on Final Rodent Infestation).

Survey on final rodent infestation: evaluation of control measures

One week after completion of the last chemical treatment with rodenticide, a sample survey on rodent infestation rates was conducted, where all environmental variables included in the "Survey on Initial Rodent Infestation" were re-evaluated. The results found were named "Final Infestation rates"; the purpose of this sample survey was to access environmental and infestation variables after implementation of rodent control measures.

The assessment consisted of a sampling analysis of total dwellings existing in the area studied. The analysis was based on the quantitative method proposed by Davis et al. (1977); this method recommends inspection of at least 435 dwellings when the area has less than 3,000 dwellings. In order to determine the sample size, an estimate of approximately 30% of the dwellings closed was carried out; with this procedure, the sample size was extended to 565 dwellings. The sampling plan chosen was the simple random sample, which considers a block as a sampling unit. The number of blocks drafted was determined by the ratio between the number of dwellings included in the sample and the average number of dwellings per block. A table of randomized numbers was utilized for the draft. In total, 13 blocks out of the 47 blocks existing in the area were drafted.

The residents' testimony on the presence or absence of rodents was also considered for evaluating rodent infestation rates in dwellings, as well as signs indicating the presence of rodent infestation, since it takes time for some signs (e.g., trails and rub marks) to disappear.

Survey on rodent re-infestation

Six months after completion of Final Rodent Infestation Survey (Evaluation of Control Measures), a new sample survey on rodent infestation was conducted in March 2006; the results of such survey were called "Re-infestation Rates". The same method proposed by Davis et al. (1977) was used to conduct this survey. Fifteen blocks were drafted, and a minor adjustment was performed in the sample so that the number of dwellings inspected did not fall below the number recommended by the method.

Statistical data analysis

Pursuant to the method proposed by Davis et al. (1977), rodent infestation rates were obtained by calculating the ratio between the total number of dwellings infested (dwellings showing signs of rodent infestation) and the total number of dwellings inspected ($n = 1{,}529$). General infestation rates (regardless of rodent species) and specific infestation rates according to the species present (*Rattus rattus*, *Rattus norvegicus* and *Mus musculus*) were calculated. Internal and external infestation rates were also estimated: (1) By internal infestation rate one should understand the cases where signs of infestation were found inside the home, that is, in the rooms of the dwelling; and (2) by external infestation rate one should understand the cases where signs of infestation were found outside the home, that is, in the backyard, garden, and in constructions adjacent to the main dwelling, as long as they were unoccupied. All results were expressed through a percentage of rodent-infested dwellings.

Frequency of each environmental variable (accessible garbage, human food available, fructiferous trees, waste material/rubbish, construction material, discarded objects, ceiling cracks, wall cracks, dense bush, building poor structure and poor sewage system) was estimated. In the following step, specific variables (food, harborage and access) were clustered to form groups of general variables, that is, general food, general harborage, and general access, which were characterized by the presence of at least one of the variables specific to food, harborage or access to the dwelling; (for example: if the building structure or access to the sewage system was equal to 1, then the general access was also equal to 1, otherwise, it was equal to 0). Frequency of both specific and general environmental variables was estimated by dividing the number of positive dwellings concerning the variable at issue by the total of dwellings inspected ($n = 1529$); the results are expressed in percentage of dwellings that presented the variable at issue.

A comparison between rates found for environmental variables and infestation variables (general and specific) in the three stages (initial, final and re-infestation rates) was accomplished by utilizing the binomial test; the confidence interval adopted was 95%.

Evaluation on the effectiveness of the control measures taken was made through the following equations: reduction rate, return rate, and difference rate, which are illustrated by the three equations below:

$$\text{Reduction rate} = (\text{Initial infestation rate} - \text{Final infestation rate} / \text{Initial infestation rate}) \times 100 \quad (1)$$

$$\text{Return rate} = (\text{Re-infestation rate} - \text{Final infestation rate} / \text{Final infestation rate}) \times 100 \quad (2)$$

$$\text{Difference rate} = (\text{Initial infestation rate} - \text{Re-infestation rate} / \text{Initial infestation rate}) \times 100 \quad (3)$$

where: reduction rate measures the difference between initial infestation rate and final infestation rate, and estimates effectiveness of control actions; return rate measures the difference between the re-infestation rate and the final infestation rate, and estimates the return of infestation six months after the last control measures were taken; and difference rate measures the difference between the initial infestation rate and the re-infestation rate, and estimates the degree of infestation six months after measures for controlling infestation ceased to be taken.

The equations were applied both to infestation variables and to environmental variables. For data statistical analysis, software programs Bioestat. 2.0© and Epi Info 3.3© for Windows were used. The significance level adopted was alpha = 0.05.

Results

Evaluation of control measures

The frequency of almost all environmental variables related to food, harborage and access sources showed a reduction in relation to the initial infestation survey. A significant reduction in rodent infestation in dwellings was also observed (Table 1).

Variable "general food" showed a reduction rate of 43.4% ($p < 0.0001$); on the other hand, the reduction rates referring to variables specific to food showed a broad variation: from 35.5% for "fructiferous trees" to only 6.0% for "human food available"; the reduction rate for variable "general harborage" was 29.7% ($p < 0.0001$); "wall cracks" was the specific variable which showed the highest reduction, registering 62.5%, whereas "construction material" was the variable which showed the lowest reduction (31.9%). Variable "general access" showed a reduction rate of 71.5% ($p < 0.0001$); among all environmental variables evaluated, "access through the sewage system" was the variable which showed the highest reduction rate 96.2% ($p = 0.0001$).

Rates referring to infestation by rodents (general and specific rates) also showed a significant reduction. The initial infestation rate, which was 40.0%, was reduced to 14.4% after control measures were implemented, showing a reduction rate of 63.8%

Table 1. Comparison between frequency of environmental variables (food, harborage and access) and rodent infestation rates in dwellings found in the Initial Infestation Survey (I-IS) and in the Final Infestation Survey (F-IS), and Reduction Rate registered after implementation of control measures on Jardim Comercial District – São Paulo, Brazil, 2005.

		% of frequency in dwellings				
	Variables	I-IS	F-IS	(IC 95%)	Reduction rate in %	(p value)
Infestation	General infestation rate	40.0	14.4	(11.7–17.2)	63.8	($p < 0.0001$)
	Roof rat	30.7	12.0	(9.4–14.6)	61.0	($p < 0.0001$)
	Norway rat	13.3	3.4	(2.0–4.9)	74.1	($p < 0.0001$)
	House mouse	1.6	0.3	(0.2–0.5)	79.0	($p = 0.0069$)
Local	Internal infestation	12.4	3.6	(2.1–5.1)	70.8	($p < 0.0001$)
	External infestation	34.0	10.8	(8.4–13.3)	68.1	($p < 0.0001$)
Source of food	General food rate	66.5	37.1	(33.3–40.9)	44.2	($p < 0.0001$)
	Accessible garbage	30.8	24.8	(21.4–28.2)	19.5	($p = 0.0007$)
	Human food available	27.3	25.6	(22.1–29.1)	6.0	($p = 0.1798$)
	Animal food	26.4	17.7	(14.7–20.8)	32.9	($p < 0.0001$)
	Fructiferous trees	7.1	4.6	(2.9–6.3)	35.5	($p = 0.0076$)
Source of harborage	General harborage rate	62.4	43.8	(39.3–47.1)	29.7	($p < 0.0001$)
	Trash/rubbish	33.5	21.5	(18.2–24.8)	35.8	($p < 0.0001$)
	Construction material	29.2	19.9	(16.7–23.0)	31.9	($p < 0.0001$)
	Discarded objects	22.6	10.3	(7.9–12.8)	54.3	($p = 0.0000$)
	Wall cracks	27.1	10.2	(7.9–12.8)	62.5	($p < 0.0001$)
	Ceiling cracks	35.3	20.0	(16.9–23.2)	43.3	($p < 0.0001$)
	Dense bush	2.4	1.5	(0.5–2.4)	38.8	($p = 0.0652$)
Access	General access rate	39.2	11.2	(8.7–13.7)	71.5	($p < 0.0001$)
	Building structure	35.1	10.8	(8.4–13.3)	69.1	($p < 0.0001$)
	Sewage system	8.7	0.3	(0.2–0.5)	96.2	($p < 0.0001$)

($p < 0.0001$). Among rates referring to specific infestation, the rate that showed the greatest reduction was infestation by house mouse, which registered 79.9%, followed by infestation by Norway rat, which registered a reduction rate of 74.1%, and roof rat, which showed a reduction rate of 61.0%. Internal infestation showed a reduction rate of 70.8% ($p < 0.0001$), while external infestation showed a reduction rate of 66.1% ($p < 0.0001$).

Evaluation on re-infestation capacity

Most environmental variables (food, harborage, and access) resumed levels above those found in the survey on final infestation (Table 2), but below levels found in the survey on initial infestation (Table 3).

The rodent infestation rate increased from 14.4% – registered in the survey on final infestation – to 26.0% in the survey on re-infestation, showing a return rate of 79.8% ($p < 0.0001$). Among specific rodent infestation rates, infestation by house mouse was the one which showed the highest return rate, that is, 318.2% ($p = 0.0274$); infestation by roof rat showed a return rate of 93.7% ($p < 0.0001$), while infestation by Norway rat showed a return rate equal to zero. Internal infestation showed a return rate of 269.2% ($p < 0.0001$), that is, almost seven-fold that of external infestation, which showed a return rate of 37.8% ($p < 0.0001$).

Table 2. Comparison between frequency of environmental variables (food, harborage and access) and rodent infestation rates in dwellings found in the Final Infestation Survey (F-IS) and in the Re-infestation Survey (R-IS), and return rate registered six months after implementation of control measures on Jardim Comercial District – São Paulo, Brazil, 2005.

		% of frequency in dwellings					
	Variables	F-IS	(IC 95%)	R-IS	(IC 95%)	Re-infestation rate in %	(p value)
Infestation	General infestation rate	14.4	(11.7–17.2)	26.0	(21.9–30.1)	79.8	($p < 0.0001$)
	Roof rat	12.0	(9.4–14.6)	23.2	(19.3–27.2)	93.7	($p < 0.0001$)
	Norway rat	3.4	(2.0–4.9)	3.4	(1.7–5.2)	0.0	($p = 1.0000$)
	House mouse	0.3	(0.2–0.5)	1.4	(0.3–2.5)	318.2	($p = 0.0274$)
Local	Internal infestation	3.6	(2.1–5.1)	13.3	(10.1–16.5)	269.2	($p < 0.0001$)
	External infestation	10.8	(8.4–13.3)	14.9	(11.6–18.3)	37.8	($p = 0.0242$)
Food source	General food rate	37.1	(33.3–40.9)	32.6	(28.2–37.1)	−12.0	($p = 0.0682$)
	Accessible garbage	24.8	(21.4–28.2)	13.3	(10.1–16.5)	−46.2	($p < 0.0001$)
	Human food available	25.6	(22.1–29.1)	6.2	(3.9–8.5)	−75.8	($p < 0.0001$)
	Animal food	17.7	(14.7–20.8)	21.1	(17.3–25.0)	19.3	($p = 0.0834$)
	Fructiferous trees	4.6	(2.9–6.3)	7.6	(5.1–10.1)	65.0	($p = 0.0212$)
Harborage source	General harborage rate	43.8	(39.3–47.1)	51.0	(46.3–55.7)	16.4	($p = 0.0061$)
	Trash/rubbish	21.5	(18.2–24.8)	17.5	(13.9–21.0)	−18.8	($p = 0.0533$)
	Construction material	19.9	(16.7–23.0)	13.3	(10.1–16.5)	−32.9	($p = 0.0029$)
	Discarded objects	10.3	(7.9 –12.8)	9.7	(6.9–12.4)	−6.6	($p = 0.3577$)
	Wall cracks	10.2	(7.9 –12.8)	14.7	(11.4–18.0)	44.5	($p = 0.0133$)
	Ceiling cracks	20.0	(16.9–23.2)	33.1	(28.7–37.5)	65.2	($p = 0.0000$)
	Dense bush	1.5	(0.5–2.4)	1.6	(0.4–2.5)	8.8	($p = 0.4324$)
Access	General access rate	11.2	(8.7–13.7)	33.3	(28.9–37.8)	198.4	($p < 0.0001$)
	Building structure	10.8	(8.4–13.3)	32.6	(28.2–37.1)	201.1	($p < 0.0001$)
	Sewage system	0.3	(0.2–0.5)	1.4	(0.3–2.5)	318.2	($p = 0.0274$)

Table 3. Comparison between frequency of environmental variables (food, harborage, access) and rodent infestation rates in dwellings found in the Initial Infestation Survey (I-IS) and in the Re-infestation Survey (R-IS), and difference rate registered on Jardim Comercial District – São Paulo, Brazil, 2005.

		% of frequency in dwellings				
	Variables	I-IS	R-IS	(IC 95%)	Difference rates in %	(p value)
Infestation	General infestation rate	40.0	26.0	(21.9–30.1)	35.0	($p < 0.0001$)
	Roof rat	30.7	23.2	(19.3–27.2)	24.5	($p = 0.0003$)
	Norway rat	13.3	3.4	(1.7–5.2)	74.1	($p < 0.0001$)
	Mouse	1.6	1.4	(0.3–2.5)	12.1	($p = 0.3748$)
Local	Internal infestation	12.4	13.3	(10.1–16.5)	−7.8	($p = 0.2689$)
	External infestation	34.0	14.9	(11.6–18.3)	56.1	($p < 0.0001$)
Food source	General food rate	66.5	32.6	(28.2–37.1)	50.9	($p < 0.0001$)
	Accessible garbage	30.8	13.3	(10.1–16.5)	56.7	($p < 0.0001$)
	Human food available	27.3	6.2	(3.9–8.5)	77.2	($p < 0.0001$)
	Animal food	26.4	21.1	(17.3–25.0)	19.9	($p = 0.0063$)
	Fructiferous trees	7.1	7.6	(5.1–10.1)	−6.4	($p = 0.3561$)
Harborage source	General harborage rate	62.4	51.0	(46.3–55.7)	18.2	($p < 0.0001$)
	Trash/rubbish	33.5	17.5	(13.9–21.0)	47.8	($p < 0.0001$)
	Construction material	29.2	13.3	(10.1–16.5)	54.3	($p < 0.0001$)
	Discarded objects	22.6	9.7	(6.9–12.4)	57.3	($p < 0.0001$)
	Wall cracks	27.1	14.7	(11.4–18.0)	45.8	($p < 0.0001$)
	Ceiling cracks	35.3	33.1	(28.7–37.5)	6.3	($p = 0.1669$)
	Dense bush	2.4	1.6	(0.4–2.5)	33.5	($p = 0.1357$)
Access	General access rate	39.2	33.3	(28.9–37.8)	14.9	($p = 0.0063$)
	Building structure	35.1	32.6	(28.2–37.1)	6.9	($p = 0.1456$)
	Sewage system	8.7	1.4	(0.3–2.5)	84.1	($p < 0.0001$)

In the survey on re-infestation, variables fructiferous trees ($p = 0.3561$), ceiling cracks ($p = 0.1669$), dense bush ($p = 0.1357$), infestation by house mouse ($p = 0.3748$), and internal infestation ($p = 0.2689$) showed levels similar (no significant difference rates) to those encountered in the initial rodent infestation survey (Table 3).

Discussion

Evaluation of control measures

Reduction in all environmental variables (food, harborage and access) after implementation of control measures indicates that the residents followed the preventive procedures recommended by the Zoonosis Control Agents team.

During the study period, 380 tons of solid residues were collected by Campo Limpo Public Service (CIUO 2005), and this procedure may have contributed to a significant reduction in trash materials/rubbish (35.8%) and discarded objects (54.3%). Reduction in construction material may also have resulted from this action; most probably, part of construction material was utilized to make improvements in dwellings, such as mending roof and wall cracks. The large reduction in access through the sewage system (96.2%) shows that the population is aware of the Norway rat habits.

Rodent infestation rates in the area studied showed a total reduction of 63.8%. Few studies found in literature utilized a methodology similar to the one applied in the present study, and only some of them evaluated the effectiveness of control measures in an urban area; other studies evaluated the impact of control actions upon only one synanthropic species, which imposes limits to comparisons.

A study conducted in 1999 in Baltimore, United States, applying a methodology similar to the one applied in the present study found a 61.3% reduction in rodent infestation rates (Lambropoulos et al. 1999). Some studies conducted in cultivated areas in Cuba applying a similar methodology to evaluate the effectiveness of the biological rodenticide *Biorat* on rodent population found a reduction between 94.6% and 98% (Villafaña et al. 1999); in some cities located in the province of Cienfuegos (Cuba), a reduction between 75.1% and 95.5% (Villfaña et al. 2000) was registered.

Some studies allow comparisons between reductions in specific infestation rates, but such comparisons enable evaluating reductions in infestation rates related only to Norway rat and house mouse. The reduction of Norway rat infestation rate found in the present study was 74.1%. A study conducted in 1987 on the valley of Aricanduva river, in São Paulo municipality, found a reduction of 95.4% in infestation rate by the Norway rat (Silva et al. 1992); in Germany, an evaluation carried out in 25 cattle farms showed a reduction in infestation rates by the Norway rat varying from 51–81%, depending on the farmer's adhesion to the control methods proposed (Endepols et al. 2003). Reduction of house mouse infestation rates in Jardim Comercial District registered 79.0%, whereas in New York City it varied between 77.7% and 100.0%, according to the formulation and the active ingredient of the rodenticide utilized (Advani 1995). Studies conducted in Australian agricultural fields located in the country's Southern region found a reduction in infestation rates by house mouse between 69% and 99% (Mutze 1989), and of 91% in soy bean fields in the mid-West region (Kay et al. 1994). It can be observed that effectiveness of the control measures taken on Jardim Comercial District is close to that encountered in other regions all over the world; it should be considered that the lower effectiveness rate of control actions against the roof rat (61.0%) jeopardizes the reduction rate concerning general infestation.

Effectiveness of strategies for rodent control adopted in each region has specific objectives, depending on the seriousness of the problem (Ramsey and Wilson 2000); thus, effectiveness of a 63.8% reduction in infestation in a given area where environmental and socioeconomic conditions are poor, as per what has been shown in the present study, might be considered satisfactory. Nevertheless, below are some pertinent considerations which might explain the results found:

(1) Utilization of a rodenticide having bromadiolone as active ingredient (utilized in pellet baits), against which synanthropic rodents resistance is documented in literature (Rowe et al. 1981; Greaves et al. 1982; Kohn et al. 2000; Endepols 2002).
(2) Behavioral mechanisms, such as neophobia, which makes the animals reject rodenticide baits placed within their environment (Brooks 1973; Fenn and MacDonald 1987; Klemann and Pelz 2006), this is valid particularly to roof rat species (Alves 1990).
(3) Inadequate baiting techniques (insufficient bait points or inadequate distribution of bait points). Studies have demonstrated that social and spatial distribution of rodent colonies around food sources may affect access to rodenticide baits, thus jeopardizing effectiveness of control measures (Fenn and MacDonald 1987; Ramsey and Wilson 2000; Endepols et al. 2003).

(4) Large availability of other food sources which would compete with rodenticides (Ramsey and Wilson 2000). It is well known that rodents usually try to find food that provides them the best nutritional balance. (Brooks 1973; Alves 1990; Klemann and Pelz 2006), thus, the rodenticide bait may be at a disadvantage when competing with other food sources existing nearby.
(5) Inherent preference and rodent's experience with food items naturally found within the environment can make them refuse rodenticide baits (Ramsey and Wilson 2000).
(6) Palatability of rodenticide bait, which may not be accepted by the roof rat which, among the three synanthropic rodent species, is the most selective in terms of food sources (Alves 1990).
(7) Excessive number of closed dwellings (29.7%) which did not undergo rodent control and which may have maintained a residual infestation, thus contributing to re-infestation in dwellings where rodent control was accomplished.
(8) Failure to investigate signs indicating infestation; the Zoonosis Agents may have mistaken old infestation signs in dwellings with current infestation signs by the time the final infestation survey was carried out.
(9) Despite the fact that environmental improvements have been implemented in the area studied, there was still large availability of food, harborage and access sources after completion of rodent control measures, and this may have favored re-infestation.

There are two possibilities to explain the greater effectiveness of the measures implemented to control Norway rat infestation in comparison to roof rat infestation: (1) The fact that the Norway rat is a generalist and opportunist omnivorous (Klemann and Pelz 2006), while the roof rat is selective in its diet (Alves 1990); thus, the Norway rat becomes more vulnerable, easily ingesting rodenticide baits; and (2) For controlling Norway rat infestation, the rodenticide was used in the powder form, spread in the interior of their burrows; effectiveness of the rodenticide is based on the animals inherent behavior – they lick their hair during grooming, thus ingesting the poison (Brooks 1973), whereas control of roof rat depends on the animal's voluntary ingestion of rodenticide baits.

Evaluation on re-infestation capacity

In the evaluation carried out six months after completion of the rodent control phase, it could be observed that some preventive measures were adhered to by the population. This was observed particularly in relation to food sources; among such sources, the only specific variable that showed an increase was the fructiferous tree, and this might be attributed to the new cycle of fructification.

Rodent infestation rates (general and specific) in dwellings showed positive return rates, this might be explained by the fact that although environment supporting capacity has been reduced by rodent control measures and by adoption of preventive procedures, the conditions remained favorable for sheltering a large population of rodents, thus allowing infestation rates to resume levels close to those formerly encountered. This emphasizes the importance of adequate environmental management and indicates that reduction or even complete elimination of rodent infestation can only be achieved by reducing environment supporting capacity (Fenn and MacDonald 1987; Alves 1990; Langton et al. 2001).

Preventive measures adopted by householders showed greater effectiveness in the case of the Norway rat, as among the three rodent species evaluated this was the only one which showed a return rate equal to zero. This is probably due to the greater association of this species with the dwelling external environment. Moreover, it seems that this species was the most affected by the intervention measures implemented, such as: Reduction in harborage sources (reduction in trash/rubbish materials, discarded objects and construction materials) and restriction of access through sewage system (Masi et al. 2008).

Quick re-infestation (six months after chemical control) found in the area studied matches the ''boomerang effect'' theory (Brazil 2002), which is similar to theories supporting other studies; these theories state that the average time for re-infestation after chemical control is between six months and one year (Bentley et al. 1959 in Alves 1990; Lambropoulos et al. 1999; Ramsey and Wilson 2000; Villafaña et al. 2000).

Two factors may have determined the quick re-infestation in the area: (1) The rodent's dispersion capacity, as the control was accomplished only in a restricted area of Campo Limpo District, and it is known that the whole region shows high rodent infestation rates (Santos et al. 2006), this would have allowed rodents, particularly the roof rat, to migrate from districts adjacent to the study area; and (2) The high rodent reproductive rate, which would have allowed survivors to quickly re-infest the area. The later hypothesis is corroborated by our knowledge on rodent's population dynamics, which foretells that: ''when a population of rodents is reduced in number, it grows on a logarithmic scale until it reaches the environment supporting capacity, and then gets stabilized'' (Brooks 1973; Ramsey and Wilson 2000). Nevertheless, the hypothesis which would better explain the quick re-infestation in the studied area is the dispersion of rodents from neighboring colonies, stimulated by their exploratory behavior (Brooks 1973) and, consequently, by migratory moves; such a hypothesis is corroborated by Brown and Tuan (2005) who attribute the quick return of rodent populations to agricultural fields to migration.

In addition, the characteristics of the area studied, such as high population density, may have favored dispersion of rodents coming from adjacent areas to the area where control was accomplished. Langton et al. (2001) suggest that a higher population density may significantly influence the dispersion of rodents from one dwelling to another, mainly if the individual's home range extends to more than one dwelling. Fenn and MacDonald (1987) consider exploratory moves within a 0.5 km radius a significant sign of migration.

Finally, it could be said that understanding the patterns of rodent moves is crucial for developing a large-scale program for rodent control. Such a program would avoid areas which have already undergone control being abandoned, thus subject to re-infestation (Alves 1990). Implementation of a program to control rodents should always ensure that all procedures included in an integrated management are followed, so that more effective and long-lasting results are achieved. In addition, investments in public policies towards social and environmental improvements should be made, not just the use of rodenticides.

Conclusions

(1) The methods adopted for controlling rodent infestation in dwellings have proven to be effective to a higher or lower degree, depending on the rodent species, but the 63.8% reduction in rodent infestation rates achieved in a short period of time (45 days) was due mainly to chemical control.

(2) The large environment supporting capacity coupled with migratory moves (dispersion) were the factors responsible for quick re-infestation in the area.
(3) Implementation of a program towards rodents control should be coupled with social and environmental initiatives, not just the use of rodenticides.

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