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Rodents are involved in the transmission to human beings of several diseases, including liptospirosis, which shows high lethality rates in São Paulo municipality. Despite this, few studies have assessed the relationship existing between urban environmental conditions and building rodent infestation. With the purpose of clarifying this relationship, an analysis has been conducted in order to quantify the influence of environmental factors upon rodent infestation on a low-income district. Diagnosis of the environmental situation has been performed to evaluate the frequency according to which harborage, food and access sources occur, and a survey on infestation rates in 2175 dwellings in the area studied. The logistic regression analysis showed that among the environmental variables, the one that showed the closest association with rodent infestation was access; followed by harborage, and food. It was concluded that poor socioeconomic and environmental conditions in the area propitiate the occurrence of high rodent infestation rates.

Keywords: rodent infestation; environmental factors; urban rodents

Introduction

In large urban centers, unplanned growth favors the emergence of precarious dwellings in areas that are inadequate for civil construction; this does not foster the practice of good hygiene habits which, in turn, contribute to the deterioration of environmental conditions. Within this context, urbanization processes leave a lot to be desired, and problems related to disposal of solid residues, drainage of pluvial waters and sewage collection and treatment have become a serious and almost uncontrollable issue (Brazil 2002). Such conditions favor the establishment of a synanthropic fauna, among it rodents, which are related to several human pathologies (Carvalho Neto 1986).

There are 1814 species of rodents in the world, and these represent approximately 40% of all species of existing mammals (Nowak 1991). Although rodents are usually considered a plague, only few species can cause economic damage and transmit diseases to human beings and domestic animals. Most probably, less than 50 species are considered to be a real plague (Alves 1990). In São Paulo municipality, only three species are classified as synanthropic rodents: Norway rat (*Rattus norvegicus*), house mouse (*Mus musculus*) and roof rat (*Rattus rattus*) (Garcia 1998).

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Synanthropic rodents have nocturnal habits, and have undergone special sensory adaptations to be able to move in the absence of light, find food and water, and escape from predators. These rodents have an acute nose, extremely sensitive taste, excellent tactile sensitivity, sharp hearing (including eco-localization capacity), high exploration and localization sense, in addition to several other physical capacities, such as jumping, climbing, digging, diving, and racing among others.

The main characteristic of these animals, however, is their high reproductivity capacity, which results from their quick sexual maturity, short pregnancy period, post-parturition estro, polyestral pregnancy, and large litters (sometimes up to 12 offsprings per litter). All these attributes together concur to an exponential growth rate when plenty of food is available (Brooks 1973). As a result, this allows synanthropic rodents to adapt to environments modified by man, which generally provide them with harborage and abundant food; this, in turn, allows them to realize their maximum reproductive potential and expand their distribution all over the world (Alves 1990; Jackson 1997).

The size of a rodent population in a given area is directly related to the maintenance of a favorable environment, to limiting factors such as food, water, harborage, parasites/diseases, predators and competitors (Jackson 1997; Channon et al. 2006). Concerning these aspects, poor environmental conditions favor the growth of this population of animals, since under these conditions a large variety of resources, such as food and harborage are available (Perret et al. 2005).

It is not the fact that rodents have an impressive reproductive capacity that has concerned sanitary authorities worldwide, but the risks these animals represent to public health. Synanthropic rodents can transmit several diseases to the human being and to domestic animals as well. The most serious ones are the bubonic plague, hantavirosis, leptospirosis, murine typhus and salmonellosis (Brooks 1973; World Health Organization [WHO] 1992).

In Brazilian urban areas, leptospirosis is the most important disease transmitted by rodents to human beings, and the primary infecting form is contact with flood waters contaminated by the urine of rodents carrying the leptospirosis etiologic agent (*Leptospira interrogans*).

Between 2001 and 2003, 3747 cases of leptospirosis were registered in Brazil, out of which 2687 (72%) occurred in urban or periurban areas as a result of several factors combined: high population density, low income and poor environmental sanitizing conditions (Arsky et al. 2005).

From 1998–2005, 2239 cases of leptospirosis in humans were confirmed in São Paulo municipality, and the lethality rate reached 14.02% (Coordenação de Vigilância em Saúde [COVISA] 2005); among these cases, 75.9% occurred in urban areas, and 44.2% of them were caught in the very domicile. During the above-mentioned period, the main forms of contamination were flood waters, (44.5%), contact with sump pits, (22.0%), contact with waste (20.3%), and direct contact with rodents (15.2%) (COVISA 2007). In the area where the present study was conducted (in 2005), 11 cases of leptospirosis were registered (Incidence coefficient 4.28/100.000 inhabitants); among these, two resulted in death (18.18% lethality rate).

In several studies, the level of rodent infestation in urban areas is associated with transmission of diseases, as well as with poor environmental sanitizing conditions (Childs et al. 1998; Channon et al. 2000; Langton et al. 2001; Villafane et al. 2001; Camero et al. 2004; Perret et al. 2005). Nevertheless, such studies do not quantify the limiting factors that influence building infestation rates, neither do they specify which of these factors might be determinant for reducing infestation and, consequently, reducing the transmission of diseases carried by rodents. Within this context, evaluation of the distribution of synanthropic rodent different species found in large Brazilian cities is important in order to understand how ecological niches existing in urban areas should be explored.

Methods

Characterization of the area studied

The area studied – Jardim comercial district (46.78°S and 23.63W) – is located in the southern region of São Paulo municipality; it is a residential neighborhood with a population of 9057 inhabitants, mostly low class people. The average income of the person responsible for the residence is around R$ 500.00/month (equivalent to approximately US$ 280); the average income in São Paulo municipality is approximately R$ 1200/month (equivalent to approximately US$ 662). A large part of the inhabitants fall into the 25–30 age bracket (Instituto Brasileiro de Geografia e Estatística [IBGE] 2000). The region's HDI is 0.72; LI (longevity index) is 0.85; EI (education index) is 0.78; and II (income index) is 0.53 (Pedroso 2003).

The streets in the area studied are all paved; the place has a total of 2175 dwellings, 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; the 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 in the area (IBGE 2000). The area relies on the following public facilities: one Basic Health Unit and five public schools; in addition, there is also a private school.

Although in recent years the area has not shown a high incidence of leptospirosis, and just one confirmed case resulting in death was registered in 2004, the area was chosen for study in view of the work developed there by the Municipality Environment Committee in the period ranging from August to November 2005, as this would facilitate implementation of deratization measures, which are the responsibility of public authorities.

Environmental diagnosis and survey on building rodent infestation rates

The area of study was fragmented in accordance with the division established by census sectors; it covered 47 blocks and included 2175 dwellings, which were visited during the month of August 2005 by Zoonosis Control Agents (five teams, each comprising three agents). For statistic analyses though, only the 1529 houses whose owners gave permission for a complete inspection were visited. The remaining 646 houses were eliminated from the study because they were either closed or their owners did not give permission for inspection.

In order to assess building infestation rates, signs indicating the presence of rodents, such as feces, rub marks, burrows, gnawing, rat runs and trails, both in the internal and the external area of each dwelling were investigated. Data referring to each dwelling inspected were registered in a form adapted from "Urban Rat Surveys". The remaining variables assessed were: dwelling characteristics, food, harborage, and infesting species (*R. rattus*, *R. norvegicus* and *Mus musculus*).

This phase of the effort was conducted according to the method proposed by the Center for Disease of Control (CDC) (Davis et al. 1977).

Statistical data analysis

The characteristics of the buildings were defined according to the type of building (residential, commercial, residential–commercial, abandoned or vacant lot) in relation to the total buildings inspected.

Infestation rates were obtained by calculating the ratio between the total of positive dwellings (dwellings showing signs of rodent infestation) and the total of dwellings inspected, and the results were expressed through a percentage of rodent-infested dwellings (Davis et al. 1977; CDC 2006). Both general infestation rates (regardless of the rodent species) and specific rates (according to the species – *R. rattus*, *R. norvegicus*, *Mus musculus*) were estimated; internal and external infestation rates were also assessed; by internal infestation one should understand infestation where signs of infestation were found in the rooms of the dwelling; external infestation occurs when signs are found in the external area of the dwelling (in the backyard, for example). A Chi-square analysis was conducted to compare the ratio of dwellings infested by *R. rattus* (roof rat) and *R. norvegicus* (Norway rat), and the difference between dwellings showing external or internal infestation was calculated with the use of a binomial test for both ratios.

Environmental variables – food, harborage and access – comprised the following groups of variables: *Food sources* = animal food, accessible garbage, human food available and frutiferous trees; *harborage sources* = waste material/rubbish, construction material, discarded objects, ceiling cracks and wall cracks, and dense bush; *access sources* = building structure and sewage system. The occurrence of each of these variables in the dwelling characterizes it as positive for the specific variable at issue. On a further step, the variables were grouped to form the general variables: general food, general harborage, general access, which were characterized by the presence of at least one of the variables specific to food, harborage or access in the dwelling. (For example, if the building structure or the sewage system was equal to 1, then general access was also equal to 1; otherwise, it was equal to 0.) The occurrence of both specific and general environmental variables was estimated by dividing the number of positive dwellings for the variable at issue by the total of dwellings inspected, and the results were expressed in percentage of dwellings.

In order to evaluate the association existing between the several environmental variables and the general and specific building infestation rates, a logistic regression analysis was conducted (Logit model), and the odds ratio (OR) for each association was calculated. For performance of such analyses, presence or absence of rodent infestation was considered as a dependent variable. The environmental variables (food, harborage and access) were considered independent variables, where 1 indicated the presence of the variable in the dwelling and 0, the absence of such variable.

For performance of these analyses two simple logistic regression models were developed:

(1) In the first model, environmental variables (animal food, accessible garbage, available human food, frutiferous trees, waste material/rubbish, construction material, discarded objects, ceiling cracks, wall cracks, dense bush, building

structure and sewage system) were independently confronted against the dependent variable infestation (general infestation). After that, sub-analyses of this model were performed confronting the same independent variable against the dependent variable infesting rodent species – *R. rattus* and *R. norvegicus*.

(2) In the second model, the association existing between the independent variable rodent species – *R. rattus and R. norvegicus* – and the dependent variable internal or external place of infestation was investigated.

As a further step, multiple logistic regression analyses were performed, and the Stepwise procedure was used to eliminate the variables not associated with the infestation, and also to assess the most closely associated variables. In all models, intercept was maintained. In this stage, the following Logit models were developed:

(1) In this first model, all environmental variables that showed to be significantly associated with rodent infestation in the univariate model (univariate model 1) were simultaneously tested against the rodent infestation dependent variable (general infestation). Afterwards, the same procedure used in the subanalysis of the infestant rodent species – *R. rattus* and *R. norvegicus* – were adopted, including the variables that showed to be significant in the subanalysis of univariate model 1.
(2) A second model where the aggregated variables general food, general harborage and general access were tested against the dependent variable general infestation were developed. A subanalysis of this model where rodent species *R. rattus* and *R. norvegicus* were used as dependent variables was also conducted.

For statistical data analysis the software programs Bioestat. 2.0®, Epi Info 3.3®, and SAS® for Windows were used, and the alpha decision level adopted was equal to 0.05 and confidence intervals 95% (CI) were estimated.

Results

Environmental diagnosis and survey on building rodent infestation

Out of the 2175 buildings existing in the area, 1529 (70.3%) were inspected by zoonosis agents and considered in the statistical data analyses; the remaining 646 buildings were excluded from the analyses.

Out of all buildings inspected, the large majority, i.e. 1378 (90.1%), consisted in dwellings. The frequency of environmental conditions that may favor rodent infestation was as follows: food sources (65.5%); harborage sources (62.4%), and access sources (39.2%) (Table 1).

The rate of building rodent infestation was 40.0% (611/1529); the most frequent species, *R. rattus*, showed a 30.7% infestation rate, followed by *R. norvegicus*, registering 13.3%, and *M. musculus*, registering 1.6%. Out of the 611 buildings infested, four (0.7%) showed simultaneous infestation by three synanthropic species, 86 (14.1%) by two species, and 514 (84.1%) by just one species (Table 2).

The difference between the ratios of buildings infested by roof rat and by Norway rat was significant ($\chi^2 = 8.81$; F.D. = 1; $p = 0.0051$). There was also a large difference between external (34.0%) and internal (12.4%) rodent infestation rates,

Table 1. Frequencies and univariate analysis of environmental variables potentially associated with rodent infestation ($n = 1529$). Jardim comercial, Campo Limpo, São Paulo, 2005.

				General infestation			
					Confidence interval (95%)		
	Variable	General frequency premises	Frequency of association	Estimate Odds Ratio	Lowest	Highest	p-value
Food source	Food in general	65.5	28.6	1.4	1.1	1.7	$p = 0.0026$
	Accessible garbage	30.8	20.9	5.5	4.3	7.0	$p < 0.0001$
	Available food	27.3	16.9	3.5	2.8	4.5	$p < 0.0001$
	Animal food	26.4	14.8	3.1	2.4	3.9	$p < 0.0001$
	Frutiferous trees	7.1	5.6	6.4	4.0	10.2	$p < 0.0001$
Harborage source	Harborage in general	62.4	37.3	20.6	14.5	29.2	$p < 0.0001$
	Useless materials/rubbish	33.5	22.0	5.3	5.3	6.7	$p < 0.0001$
	Construction material	29.2	16.6	2.7	2.7	3.4	$p < 0.0001$
	Discarded objects	22.6	15.6	4.9	4.9	6.3	$p < 0.0001$
	Wall cracks	27.1	19.0	5.7	5.7	7.3	$p < 0.0001$
	Ceiling cracks	35.3	24.1	6.6	6.6	8.3	$p < 0.0001$
	Dense bush	2.4	1.9	5.0	5.0	10.7	$p < 0.0000$
Access	Access in general	39.2	33.3	45.9	45.9	62.2	$p < 0.0001$
	Building structure	35.1	29.7	30.1	30.1	40.3	$p < 0.0001$
	Sewage system	8.7	7.8	15.6	8.9	27.5	$p < 0.0001$

Table 2. Distribution of synanthropic rodents throughout the dwellings inspected ($n = 1529$) found in the survey on building infestation. Jardim comercial district, São Paulo, 2005.

Infesting species	*N*	%
Roof rat	387	63.3
Norway rat	121	19.8
Mouse	6	1.0
Roof rat + Norway rat	72	11.8
Roof rat + house mouse	7	1.1
Norway rat + house mouse	7	1.1
Roof rat + Norway rat + house mouse	4	0.7
Non-identified species	7	1.1
Total of dwellings infested	611	100.0

and external infestation rate was 2.7 times higher than internal infestation (CI 2.32–3.20; $p < 0.0001$).

Association between environmental variables and building rodent infestation rates

The results of the association between environmental variables and rodent infestation found in the simple logistic regression analysis show that all variables studied bear a strong association with both general infestation (Table 1) and specific infestation, that is, infestation by *R. rattus* (Table 3) and by *R. norvegicus* (Table 4). Thus, all these variables were added to the multiple logistic regression model, since no multicolinearity neither confusion among the independent variables could be observed, as shown in the multivariate model correlation matrix (correlation matrix not presented).

The multiple logistic regression analysis (Table 5) performed to check the association existing between environmental variables (food, harborage and access) and building infestation rates showed a stronger association between rodent infestation and general access sources (OR 24.5; CI 17.8–33.9; $p < 0.0001$), followed by harborage sources (OR 4.1; CI 2.7–6.4; $p < 0.0001$) and food sources (OR 2.1; CI 1.5–2.9; $p < 0.0001$) (Table 3).

Among the specific environmental variables that showed a significant association with rodent infestation were: *Food sources* – frutiferous trees – (OR 2.1; CI 1.1–4.0; $p < 0.0001$) and accessible garbage (OR 2.1; CI 1.5–3.0; $p < 0.0001$); *harborage sources* – ceiling cracks (OR 1.7; CI 1.2–2.3; $p = 0.0018$), waste material/rubbish (OR 1.7; CI 1.2–2.4; $p < 0.0001$) and dense bush (OR 3.1; CI 1.1–9.1; $p = 0.0387$); *access sources* – building structure (OR 22.7; CI 16.1–31.7; $p < 0.0001$) and sewage system (OR 19.9; CI 10.5–37.7; $p < 0.0001$). Analysis of place infestation rate showed a significant association between internal infestation and roof rat (OR 31.0; CI 19.0–50.7; $p < 0.0001$). As to external infestation, both roof rat (OR 37.8; CI 20.3–36.2; $p < 0.0001$) and Norway rat (37.8 CI 22.0–64.9; $p < 0.0001$) showed a significant association.

Association between the most frequent rodent species and general food rate showed that food availability has no influence upon the possibility that the building becomes infested by *R. norvegicus* (OR 1.5; IC 1.1–2.2) or *R. rattus* (OR 2.0: IC 1.4–2.0). Some specific food sources, such as animal food, may favor infestation by one or other species, as for example animal food, which shows a significant association

Table 3. Frequencies and univariate analysis of environmental variables potentially associated with roof rat infestation ($n = 1529$). Jardim comercial, Campo Limpo, São Paulo, 2005.

				Rattus rattus			
					Confidence interval (95%)		
	Variable	General frequency dwelling	Frequency of association	Estimate Odds Ratio	Lowest	Highest	*p*-value
Local	Internal infestation	12.4	11.1	31.0	19.0	50.7	$p < 0.0001$
	External infestation	34.0	24.7	27.1	20.3	36.2	$p < 0.0001$
Food source	General food	65.5	28.8	1.3	1.1	1.7	$p = 0.0075$
	Accessible garbage	30.8	16.8	4.8	3.8	6.0	$p < 0.0001$
	Available food	27.3	13.9	3.5	2.7	4.4	$p < 0.0001$
	Animal food	26.4	12.7	2.8	2.2	3.6	$p < 0.0001$
	Frutiferous trees	7.1	4.2	3.5	2.4	5.3	$p < 0.0001$
Harborage source	General harborage	62.4	29.2	22.2	14.3	34.7	$p < 0.0001$
	Useless material/rubbish	33.5	17.6	4.5	3.6	5.7	$p < 0.0001$
	Construction material	29.2	13.2	2.5	2.0	3.2	$p < 0.0001$
	Discarded objects	22.6	12.4	4.0	3.1	5.1	$p < 0.0001$
	Wall cracks	27.1	15.9	5.5	4.3	7.0	$p < 0.0001$
	Ceiling cracks	35.3	19.3	5.6	4.4	7.0	$p < 0.0001$
	Dense bush	2.4	1.2	2.3	1.2	4.4	$p = 0.0123$
Access	General access	39.2	26.0	23.1	17.2	30.9	$p < 0.0001$
	Building structure	35.1	24.8	23.9	18.0	31.8	$p < 0.0001$
	Sewage system	8.7	4.4	2.6	1.8	3.7	$p < 0.0001$

Table 4. Frequencies and univariate analysis of environmental variables potentially associated with Norway rat infestation ($n = 1529$). Jardim comercial, Campo Limpo, São Paulo, 2005.

				Rattus norvegicus			
					Confidence interval (95%)		
	Variable	General frequency in building	Frequency of association	Estimate Odds Ratio	Lowest	Highest	*p*-value
Local	Internal infestation	12.4	2.8	2.2	1.5	3.1	$p < 0.0001$
	External infestation	34.0	12.4	37.8	22.0	64.9	$p < 0.0001$
Food source	Food in general	65.5	9.7	1.4	1.0	1.9	$p = 0.0298$
	Accessible garbage	30.8	7.2	3.1	2.3	4.2	$p < 0.0001$
	Available food	27.3	5.3	1.9	1.4	2.6	$p < 0.0001$
	Animal food	26.4	4.6	1.6	1.2	2.2	$p = 0.0044$
	Frutiferous trees	7.1	2.5	4.0	2.6	6.2	$p < 0.0001$
Harborage source	Harborage in general	62.4	12.3	8.6	5.1	14.4	$p < 0.0001$
	Useless material/rubbish	33.5	7.6	3.2	2.3	4.3	$p < 0.0001$
	Construction material	29.2	6.1	2.3	1.7	3.1	$p < 0.0001$
	Discarded objects	22.6	5.7	3.1	2.2	4.2	$p < 0.0001$
	Wall cracks	27.1	5.8	2.4	1.7	3.2	$p < 0.0001$
	Ceiling cracks	35.3	7.7	2.9	2.2	4.0	$p < 0.0001$
	Dense bush	2.4	1.0	5.0	2.6	9.8	$p < 0.0001$
Access	Access in general	39.2	10.7	8.4	5.8	12.1	$p < 0.0001$
	Building structure	35.1	8.2	3.5	2.6	4.8	$p < 0.0001$
	Sewage system	8.7	5.3	16.1	10.9	23.9	$p < 0.0001$

Table 5. Environmental variables associated with rodent infestation by multiple logistic regression ($n = 1529$). Jardim comercial, Campo Limpo, São Paulo, 2005.

		General infestation				Infesting species: *Rattus rattus*				Infesting species: *Rattus norvegicus*			
	Variables	OR*	CI 95%**		*p*-value	OR	IC 95%		*p*-value	OR	IC 95%		*p*-value
Food source	Food general	2.1	1.5	2.9	$p < 0.0001$	2.0	1.5	2.7	$p < 0.0001$	1.5	1.1	2.2	$p = 0.0173$
	Accessible garbage	2.1	1.5	3.0	$p < 0.0001$	1.9	1.4	2.6	$p < 0.0001$		Non-associated		
	Animal food		Non-associated			1.5	1.1	2.1	$p = 0.0076$		Non-associated		
	Frutiferous trees	2.1	1.1	4.0	$p = 0.0100$		Non-associated			2.2	1.4	3.7	$p < 0.0001$
Harborage source	Harborage general	4.1	2.7	6.4	$p < 0.0001$	4.8	2.9	8.0	$p < 0.0001$	2.6	1.4	4.8	$p < 0.0001$
	Useless material/rubbish	1.7	1.2	2.4	$p < 0.0001$	1.6	1.2	2.2	$p = 0.0001$				
	Construction material		Non-associated				Non-associated			1.4	1.0	2.1	$p = 0.0400$
	Wall cracks		Non-associated			1.6	1.2	2.2	$p = 0.0033$		Non-associated		
	Ceiling cracks	1.6	1.2	2.4	$p = 0.0018$	1.4	1.0	1.9	$p = 0.028$	1.5	1.0	2.2	$p = 0.0159$
	Dense bush	3.1	1.1	9.1	$p = 0.0387$		Non-associated			2.8	1.2	6.1	$p = 0.0084$
Access	Access general	24.5	17.7	33.9	$p < 0.0001$	11.7	8.5	16.0	$p < 0.0001$	4.9	3.2	7.3	$p < 0.0001$
	Building structure	22.7	16.2	31.9	$p < 0.0001$	13.3	9.6	18.4	$p < 0.0001$	2.3	1.5	3.4	$p < 0.0001$
	Sewage system	19.9	10.5	37.7	$p < 0.0001$		Non-associated			13.8	9.1	20.9	$p < 0.0001$

*OR, odds ratio; **CI, confidence interval.

only with *R. rattus*, and frutiferous trees, which shows a significant association with *R. norvegicus*. Accessible garbage, on the other hand, is associated with both species.

As to availability of harborage in the building, association between the infesting species and the harborage general rate showed that there is no difference between the probabilities that the building is infested by *R. rattus* (OR 4.8; IC 95% 2.9–8.0; $p < 0.0001$) or by *R. norvegicus* (OR 2.6; IC 1.4–4.8; $p < 0.0001$). The analysis of specific harborage sources show that ceiling cracks are associated with both species, whereas wall cracks are associated with only *R. rattus*, and dense bush is associated with *R. norvegicus*.

Analysis of specific access sources shows that the buildings providing access to rodents through the building structure have greater possibility of being infested by *R. rattus* (OR 13.3; IC 95% 9.6–18.4; $p < 0.0001$) than by *R. norvegicus* (OR 2.3; IC 95% 1.5–3.4; $p < 0.0001$). In the buildings where access is provided only through the sewage system, association is significant only in the case of *R. norvegicus* (OR 13.8; IC 95% 9.1–20.9; $p < 0.0001$).

Discussion

Environmental diagnosis and survey on building infestation rates

The results obtained show that there is large availability of food, harborage and access sources in the area studied, which favors building rodent infestation. Thus, the huge offer of food sources is likely to be a reflex of bad conditioning habits, as is the case of accessible garbage and available food, or inadequate sanitizing practices.

The large availability of harborage sources derives from the habit, common among the population, of keeping materials that might perhaps be utilized later on, such as construction material and useless objects. Accumulation of waste material/rubbish could probably be explained by the fact that the houses in the area are frequently undergoing renovation, and also by the difficulty the population has to give an adequate destination to such materials, as there is not a municipal system for collecting solid residues.

As to ceiling and wall cracks, these are associated with the poor conditions of the dwellings in the area which, in general, do not have adequate finishing. The same consideration could be made in relation to easy access availability through the building structure. As to access through the sewage system, IBGE data (2000) demonstrated that 30.4% of the houses are not served by a sewage collection system, thus the dwellers have to build channeling systems which carry the rejects directly to the stream running in the area, thus favoring the coming of rodents through the sewage system, particularly *R. norvegicus*.

It was observed that 12.4% of constructions in the area show internal rodent infestation, which demonstrates that the structure of the dwellings is poorly built and maintained, thus allowing easy access and providing harborage to rodents inside the internal environment, mainly *R. rattus* which according to Alves (1990) is a predominant species in domiciles.

The rodent building infestation rates found in Jardim comercial (40.0%) are above those encountered in developed countries, but below those encountered in some Latin American localities. Unfortunately, data from other Brazilian localities that would allow comparisons are not available. But since socio-economic and environmental conditions in other Brazilian urban areas, such as Salvador and Rio de Janeiro are similar, it is expected that infestation rates in these cities are also similar to those found in Jardim comercial.

In the United Kingdom, infestation rates have been maintained below 5% (Department for Environmental Food and Rural Affairs [DEFRA] 2005) along the years. According to a study conducted by Childs et al. (1998) in New York City, depending on the socio-economic conditions prevailing in each region, infestation rates varied from 8.3–27.3%. Another study conducted in 2000 in nine municipalities in the province of Cienfuego, Cuba, demonstrated that the infestation rates varied from 27.2% in Rodas municipality to 73.0% in Cienfuegos municipality (Villafaña et al. 2000). In 2004, high rodent infestation rates (70.8%) were registered in the city of Tumero, Venezuela; similar to what has happened in Jardim comercial, the predominant species was *R. rattus*, showing an infestation rate of 68% (Camero et al. 2004), more than double the number registered in Jardim comercial (30.7%).

According to the Center for Disease Control and Prevention (CDC – USA) classification, the rodent infestation rate found in Jardim comercial can be considered quite high, since this center considers that building infestation rates equal or above 26% involve a high risk for transmission of diseases (Davis et al. 1977; CDC 2006).

The rate of infestation by *R. norvegicus* (13.3%) is considered high, while the rate of infestation by mouse (1.6%) is equivalent to that found in developed countries. For purposes of comparison, it could be observed that in the UK, in 2001 the registered rate of infestation by *R. norvegicus* was 2.9%, and that by *M. musculus* was 1.4% (DEFRA 2005). Two hypotheses could be raised to explain the low rate of infestation by mouse registered in the area studied: the first is the difficulty in spotting traces of such species, as this demands careful inspections. Thus, the rate of infestation by *M. musculus* found in this study may have been underestimated. The second point is that according to what has been found through field observations, *R. rattus* species is occupying intradomicile harborage, such as cupboard drawers and stove heaters, formerly exclusive to *M. musculus*, thus being excluded by interspecific competition.

Predominance of *R. rattus* suggests that a change in the profile of rodent infestation in São Paulo municipality has occurred in recent years. A survey on building infestation conducted in 1987 on Vale do Rio Aricanduva (eastern region of São Paulo municipality) found that the predominant species was *R. norvegicus*; out of the 9381 buildings existing in the area, 1022 (10.9%) were infested by rodents, but the presence of *R. rattus* (Silva et al. 1992) was not registered. Though it should be observed that the large majority of houses infested in the area studied showed infestation by a single species (84.1%; $n = 611$), which shows a possible interspecific competition, particularly between *R. rattus* and *R. norvegicus*, suggesting that the availability of ecological niches may be favoring the former, as this species was found in 63.3% of the domiciles inspected. On the other hand, although the presence of *R. rattus* has been confirmed, the rate of infestation by *R. norvegicus* registered on Vale do Rio Aricanduva (10.9%) is similar to that found in Jardim comercial (13.3%), indicating that there has been no change in relation to the presence of this species in face of the competition with *R. rattus*, and that this species may be occupying niches different from those occupied by *R. norvegicus*. Nevertheless, final results will be achieved only after complementary studies are conducted, which will allow understanding the spatial and temporal distribution of these two rodent species in São Paulo municipality.

The high rate of infestation by *R. rattus* (30.7%) registered may be explained by poor urbanization processes designed for the area, where a large quantity of dwellings are built in areas: (i) lacking adequate infrastructure; (ii) having high population density; (iii), having a large number of geminated houses; and (iv) aerial structures, such as electric cables, facilitate the vertical and horizontal movement of such animals (Brazil 2002). In addition, the large availability of food, harborage and access allows dispersion of these species throughout the buildings.

Environmental conditions and rodent infestation

The results of statistical analyses showed that the associations found between the variables food, harborage and access and building rodent infestation (both general and specific) are compatible with what is known about rodents synanthropic biology.

Simple logistic regression analyses showed that the environmental variables investigated are adequate for studying the dynamics of urban rodent populations, since they show a significant association with building infestation. Moreover, these analyses showed a degree of sensitivity enough to point out differences in associations with the two rodent species studied (*R. rattus* and *R. norvegicus*), the species *M. musculus* was not considered in this phase of the study in view of its low occurrence in the buildings infested (1.6%; $n = 24$). This model did not consider the water source variable because the study was based on the model proposed by Davis et al. (1977), where such variable is not included.

Upon analysis of the results obtained through the multivariate model, it can be observed that the significant association between accessible garbage and rodents is in accordance with literature reports which consider garbage as the most important food source for rodents in urban environments, as it provides substantial quantities of water and nutrients (Brooks 1973). Frutiferous trees are one of the least common sources of food (7.1%), but the produce of a single tree can nourish a whole colony of rodents and determine infestation of more than one building; in addition, its association with *R. norvegicus* is in accordance with the peridomiciliary habits of such species (Brooks 1973; Brazil 2002).

The association between animal food and *R. rattus* is corroborated by other studies, such as that developed by Bevilacqua et al. (2004) who, in research conducted in a veterinarian hospital in Minas Gerais, Brazil, found that the predominant infesting species was *R. rattus*, and that the largest number of captures occurred in the sector of pet animals (dogs and cats); this suggests an association between the presence of such animals and the habit of leaving food exposed for extended periods of time.

The results of specific harborage availability showed associations compatible with the characteristics of each species. Thus, *R. rattus* showed a significant association with ceiling and wall cracks, which is in agreement with the species scansorial habits (Alves 1990), while *R. norvegicus* showed a significant association with dense bush, as it was expected, in view of the species peridomiciliary and fossorial habits (Brooks 1973; Brazil 2002).

As to access sources, a greater association between *R. norvegicus* and access through the sewage system was observed, which can be attributed to the species' aquatic characteristics (Brooks 1973; Langton et al. 2001; Brazil 2002).

As illustrated in Table 3, another aspect to be approached is that although *R. rattus* is considered a predominantly intradomiciliary species (Alves 1990), the results obtained in the present study demonstrate that this species may occur both in the building's internal and external environment. *Rattus norvegicus*, on the other hand, is a predominantly peridomiciliary species. Nevertheless, when environmental conditions are favorable, the two species may explore both environments, demonstrating the adaptative plasticity of these animals (Advani 1995).

Greater activity of these rodents in some areas suggests that their activity does not have a random distribution, and that certain environmental factors can make a given locality more attractive than others (Channon et al. 2006). The factor that limits the distribution of each species on each building is likely to be inter-specific competition (Amarasekare 2003). Thus, in the absence of competitors, a given species may occupy both internal and external niches.

Finally, it could be said that the level of building infestation in a given area is a reflection of ecological factors prevailing in the urban environment in terms of key resources (Langton et al. 2001) and that, as demonstrated by the results obtained, among these resources the most important ones are access and harborage. In addition, it is important to know the characteristics of the dwelling, as they define the possibility of infestation, as well as the expected level of infestation. Thus, adequate control of several factors, such as the construction of dwellings having an adequate infrastructure, would result in a reduction in building rodent infestation rates, as access and harborage availability would be reduced. It can thus be concluded that any control action aimed at reducing building rodent infestation rates could not be taken without government investment in habitational, educational, environmental sanitation, and income increment areas.

Conclusions

- The building rodent infestation rates registered in the area studied are considered quite high (40.0%), thus configuring a public health concern.
- The poor socio-economic and environmental conditions prevailing in Jardim comercial favors the occurrence of high building rodent infestation rates.
- The predominant species of synanthropic rodent infesting Jardim comercial is *Rattus rattus*, registering a 30.7% building infestation rate.
- Out of the three limiting factors studied, the one that shows greater association with rodent infestation is access. The possibility that a dwelling becomes infested increases 24.2 times when an access source is available; 4.2 times when a harborage source is available, and 2.1 times when a food source is available.
- Adoption of sanitation, educational, housing and income public policies would be quite beneficial for reducing high building rodent infestation rates in urban areas such as Jardim comercial.

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